Investigation of Fecal Coliform Sources in Juanita Creek Basin

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Purpose of the Study

Juanita Swimming Beach (Figure 1) has had more closures for exceeding fecal coliform bacteria criteria than any other public swimming beach in King County. The bacterial counts that result in these beach closures have been the highest measured at any of the approximately thirty monitored swimming beaches in King County for the eleven years swimming beach monitoring has been routinely done (http://green.kingcounty.gov/swimbeach/BeachData.aspx?locator=0806SB). The beach has been closed to swimming by the Kirkland Parks Department and Public Health Seattle and King County (PHS&KC) more frequently and for longer periods than any of the routinely monitored public swimming beaches in the program (http://green.kingcounty.gov/swimbeach/).

Figure 1. Juanita Beach Park, showing routine sampling water locations and the wooden barrier that extends vertically from the walkway surrounding the swimming area. Immediately to the NW (left in the photo) Juanita Creek can be seen discharging parallel to the shore and directed toward the swimming area. The deflection of the stream mouth and accumulation of sand along the west side of the walkway indicate shore currents predominantly move from NW to SE (left to right).

Several sources of bacteria have been identified at Juanita Beach, but quantitative estimates of the relative contributions from the sources have not been made. Contributing to the high fecal coliform bacteria counts in the swimming beach waters is a large population of non-migratory Canada Geese, bacterial loading of undetermined sources from the adjacent Juanita Creek (Figure 2), and reduced water circulation within the swimming area of this beach.

Reduced water circulation within the swimming area is hypothesized to contribute to the high bacteria counts and frequent beach closures. A vertical surface to bottom wooden board wave barrier is attached to the over-lake walkway surrounding the beach which physically decreases wave action and water circulation in the swimming area. The barrier was installed to reduce erosion of the sand beach from wave action from the long southern fetch from the SR 520 floating bridge to Juanita Beach. By reducing wave action on the beach, the barrier also decreases water circulation and exchange within the swimming area.

During the beach closures in 1995, a pump circulation system was installed in an attempt to increase water circulation and dilute the high bacteria water in the swimming area. The pumps were undersized and water movement was insufficient to affect the bacterial counts. Several of the vertical boards have since been removed from the barrier to increase water circulation. Temporary removal of the barrier was suggested, but Washington Department of Fish and Wildlife indicated that they would not issue a permit to replace the barrier if it were removed and protection of the sand beach is a primary maintenance need for the park.

Attempts have been made to reduce the bacterial loads from the non-migratory Canada Geese at the swimming beach. Maintenance removal of goose droppings combined with increased harassment of geese by dogs and park personnel have been used to reduce the goose contribution to bacterial loads. While beach closures have not been as frequent since the mid 1990s, nor the maximum bacteria counts as high, elevated bacterial counts and beach closures for high counts still periodically occur at Juanita Beach.

While no detailed current studies have been conducted in Juanita Bay, the long wave fetch is known to influence water movement within the bay, pushing water eastward along the shore as evidenced by the nearly ninety degree turn of Juanita Creek toward the swimming area directly after entering the lake (Figure 1). The frequent high bacteria counts in the creek are discharged adjacent to the beach, creating a water contact risk for the public at the swimming beach, and through much of the Juanita Creek watershed where people may come into contact with the water. The creek within the Juanita Beach Park is a popular area for children to play and is often covered with footprints and dotted with the remains of sandcastles.

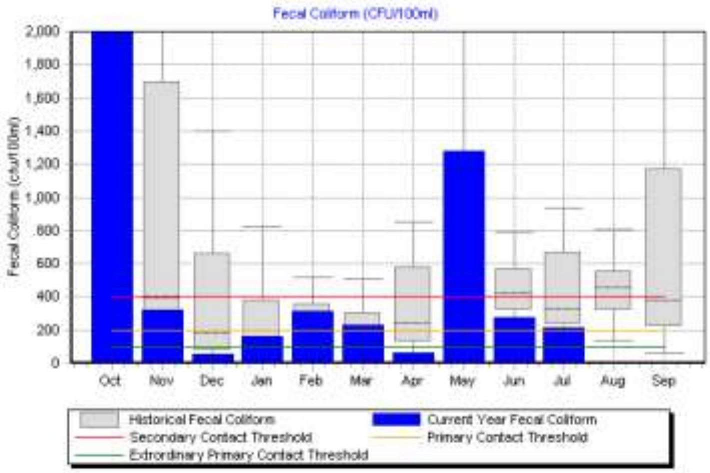


Figure 2. Current water year fecal coliform bacteria at locater 0446 for 2009 compared to historical data (1976-2005), and State water quality threshold values.

Juanita Creek was designated a *Class AA* water body under the 1997 Washington State Water Quality Standards for Surface Waters, WAC173-201A rules. Under the updated 2003 rules, Juanita Creek is categorized as *Core Salmon Migration and Rearing Habitat for aquatic life use* and for “Extraordinary Primary Contact Recreation” (not to exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples [or any single sample when less than ten sample points exist] obtained for calculating the geometric mean value exceeding 100 colonies/100 mL for recreational use). Both of the routine King County sampling sites in Juanita Creek (O446 and C446 described below) are listed on the 2004 Washington Department of Ecology’s (Ecology) 303(d) list for violation of dissolved oxygen (DO), temperature and fecal coliform (FC) bacteria standards.

Since 1976 King County has routinely monitored water quality and samples have been collected monthly from two sites along Juanita Creek. Station 0446 is located at the USGS gauging station north of Juanita Park. Station C446 is located at the bridge on NE 128th, east of 100th NE. The City of Kirkland monitors seven sites on Juanita Creek and three of its tributaries weekly. Four of the sample sites, 16, 17, 33, and 34 are located on the main stem of Juanita Creek, sample site 27 is located on Billy Creek (lower West) Tributary, sample site 81 is located on Totem Lake (lower East) Tributary and sample site 39 is taken from the unnamed tributary site. The weekly monitoring began in July 2007 and is on-going (Figure 3).

Figure 3. City of Kirkland Juanita Creek *E.coli* monitoring sites.

As part of the protocol developed for the King County Swimming Beach Monitoring Program (King County 2005) streams that discharge adjacent to swimming areas are sampled synoptically with the swimming beaches. These streams are assumed to have a high potential for contributing high loads of bacteria from their urbanized watersheds. At Lake Washington swimming beaches, Juanita Creek is sampled synoptically with Juanita Beach; Thornton Creek in the City of Seattle is sampled with Matthews Beach. On Lake Sammamish, Idylwood Creek is sampled with Idylwood Beach and Issaquah Creek with the beach at the State Park. These streams are in public parks and all attract primary contact use. It is assumed that control of the bacterial pollution within these streams will result in an improvement of the water quality both in the streams, addressing the 303(d) listing of these particular stream segments, and the adjacent swimming beaches, resulting in fewer closures due to excessive bacteria and addressing the 303(d) listing at the beaches.

Juanita Creek frequently has high fecal coliform bacteria counts that exceed water quality criteria, and bacteria counts in this creek are consistently some of the highest of the streams monitored by King County (Figure 2; http://green.kingcounty.gov/WLR/Waterres/StreamsData/Bacteria.aspx?Locator=0446). The City of Kirkland has also identified several sources of bacterial pollution entering the stream from cross connections, broken sewer lines, and overland discharges of sewage from grease clogged pipes *Baseline Survey of E. coli in Juanita Creek, Kirkland, Washington, July 2007-Feb 2008* (McLaughlin 2008) and *Correlating precipitation, discharge and water temperature to E.coli concentration in Juanita Creek*

(Gaertner 2009). This survey is designed to support the identification and location of remaining bacterial sources so that they can be eliminated.

This bacterial survey was funded by a 319 Directed Implementation Fund (DIF) grant from WA State Department of Ecology to the City of Kirkland in partnership with King County to locate fecal coliform bacteria sources in the Juanita Creek basin which are assumed to contribute to the frequent bacterial exceedances in the stream and closures of Juanita Beach, and address the 303(d) listing of Juanita Creek and the swimming beach. It is impossible to correct bacterial sources if the locations of the sources are unknown. This survey used multiple sampling within the Juanita Creek watershed to isolate short stream segments and delineate small portions of the basin that contribute to these stream segments where bacterial loads are entering the stream. When the potential bacterial sources are located to somewhere within these small sub-basin areas, more detailed source control investigations can be conducted in as small of a geographic area as possible to pinpoint the source of the bacteria and potentially eliminate the pollution. If this methodology is successful in Juanita Creek and beach, this protocol can be used at all of the public swimming beaches that are impacted by urban stream discharges. A collaborative project with Kirkland and King County will be phased over the next two years.

Phase I (Year 1) - Investigate and identify reaches of concern along Juanita Creek through periodic intensive synoptic fecal coliform samplings during summer low flow conditions. Investigations will also involve stream walks and windshield surveys to document potential sources. If identified sources warrant immediate required actions (e.g., sewer line breaks), then relevant partners, under their legal authority, will respond accordingly during Phase I.

Phase II (Year 2) - Correct identified fecal coliform sources by implementing on-the-ground best management practices and supporting local agency activities. Phase I investigation results can help guide implementation actions. In addition to DIF funding, other funding such as Centennial Grants may be pursued to implement actions needed. The actions may include, but are not limited to, the following:

- Sanitary surveys or dye testing by Public Health Seattle-King County to identify and confirm failing on-site septics and notify homeowners to make required corrections.
- Extend sewer service to un-sewered areas by Northshore Utility District. The District has pursued a Utility Trust Fund Loan to extend sewer capability to un-sewered areas in the basin. Ecology provided them with a letter of support.
- Riparian restoration projects to restore and enhance the riparian corridor where needed. Healthy riparian habitat helps filter out a variety of pollutants in stormwater runoff, including fecal coliform.
- Source control education to the public, such as pet waste, on-site septic maintenance, and restaurant/food waste management.

This report documents findings from this Phase I project and identifies follow-up actions needed under a separately funded Phase II project.

Project Methodology
Experimental Design

Sampling Design and Rationale

Sample locations were selected throughout the Juanita watershed in an attempt to bracket short linear segments of Juanita Creek and facilitate the location and subsequent control of undetected bacterial sources. The short stream segments bracketed by the sampling sites were used to define small sub basins to focus specific source identification efforts in Phase II of this project. Selection of sampling locations was constrained by safety and time to access particular locations and permission by property owners to sample on private property (Figure 4; Table 1).

The focus of this survey is to isolate signals of potential bacterial sources to short segments of stream, and once located, to initiate corrective actions. While the design has inherent variability issues, it is assumed that with sequential sampling upstream to downstream, any contributors to the bacterial count variability will be similar at adjacent sites and that the difference between adjacent sampling sites will not be significantly influenced by local variability. This study is neither a loading study nor a TMDL and quantification of the absolute counts and loadings are secondary to narrowing the area to search for bacterial sources by the relative differences between adjacent sampling locations.

Higher variability with low results is especially noticeable for bacteria. Analytical precision is determined by performing a duplicate analysis on the same sample and comparing the results. Laboratory duplicates by the membrane filtration method are performed by removing aliquots from the sample bottle as two separate sub-samples, and duplicating all steps including preparation of dilutions. Duplicate sample results are evaluated by method 9020B.4 prescribed in Standard Methods for the Examination of Water and Wastewater, 20th ed., 1998. Briefly, this requires that the log-transformed difference between the two duplicate results be compared to the mean of the log-transformed differences for the previous 15 sample pairs. The acceptance criterion is to be within 3 standard deviations of this latter value. Failure to meet the criterion is cause to evaluate the entire sample batch for compliance and applicability of the calculation, before qualifying or rejecting the data set.

The method used at the King County Environmental Lab (KCEL) for fecal coliform testing by membrane filtration (MF) is Standard Method 9222 D, Standard Methods for the Examination of Water and Wastewater, 20th Edition. Dilutions are selected to provide a targeted recovery range of between 1 and 6,000 cfu/100ml.

If this survey results in the development of a TMDL, the following will be considered, *Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters* (Mathieu, 2006 at http://www.ecy.wa.gov/biblio/0603044.html).

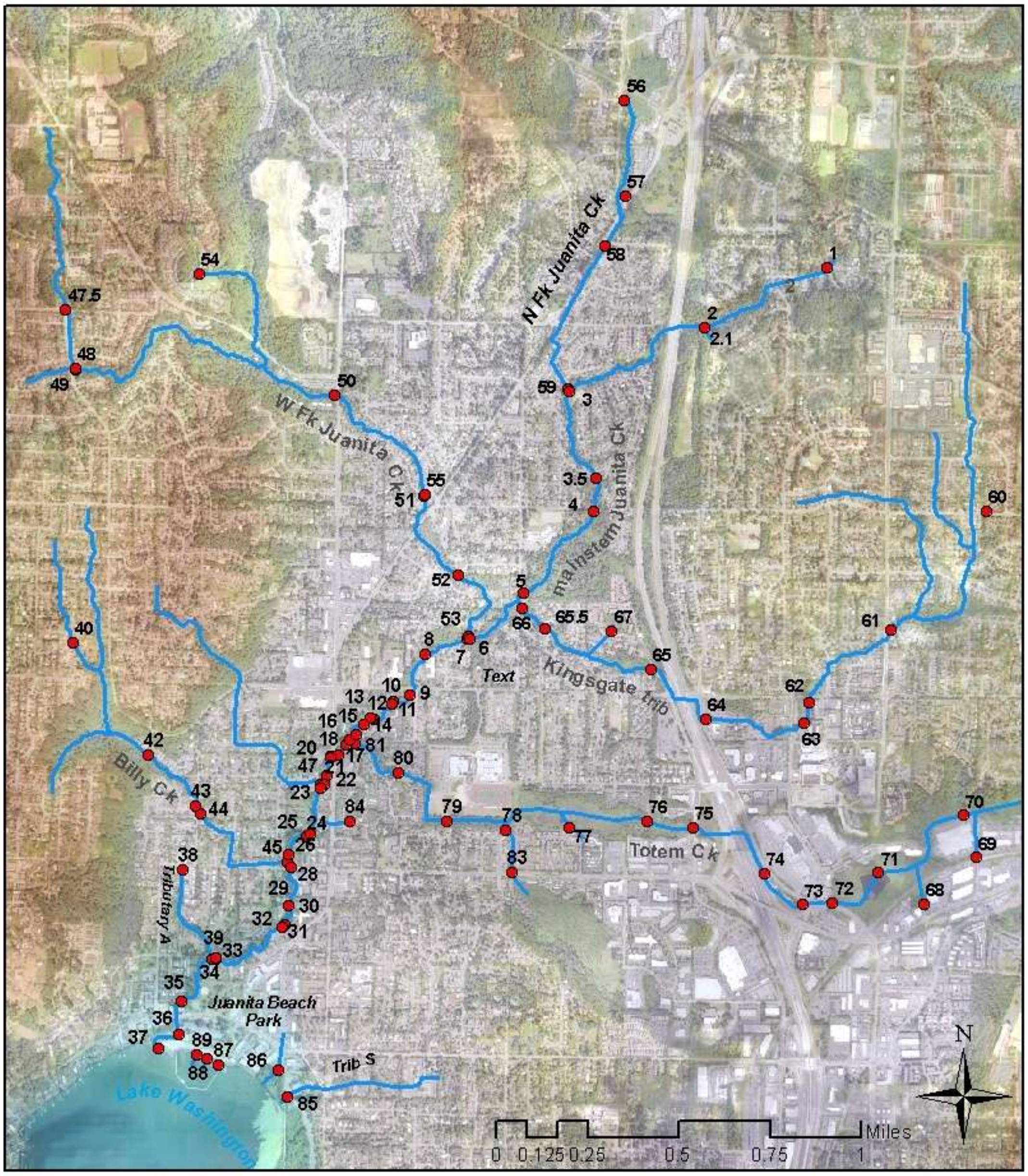


Figure 4. Sampling locations for the Juanita Creek fecal coliform bacteria study. Samples were collected in the morning (AM) and afternoon (PM) on July 30, August 27, and September 24, 2008.

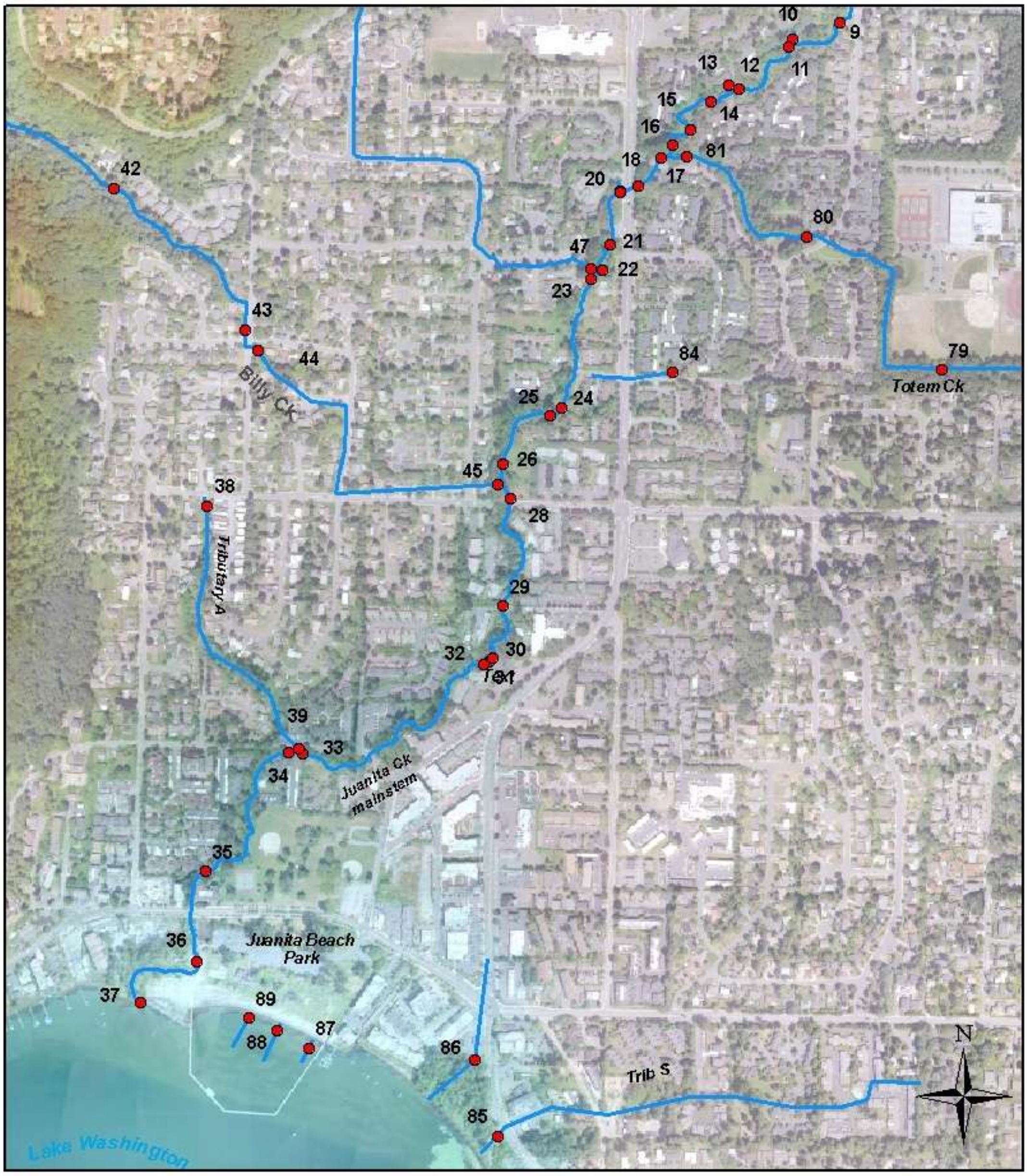


Figure 4b. Detail of sampling locations for the lower portion of Juanita Creek. Samples were collected in the morning (AM) and afternoon (PM) on July 30, August 27, and September 24, 2008.

Miles
0 0.05 0.1 0.2 0.3

Table 1. Fecal coliform sampling sites in Juanita Creek basin July, August, and Sept. 2008				
		Site Descriptions		
study ID	locator	site description	state plain coord X	state plain coord Y
1	446-1	open channel downstream of culvert W of 122nd Ave NE and N of NE 148th St	1309203	271192
2	446-2	open channel just upstream of lower footbridge below swim club off NE148th Ct	1307439	270322
2.1		stormwater outfall puddle on S side of channel by site 2 bridge	1307440	270319
3	MM446	open main channel downstream of footbridge off of NE 143rd Pl	1305483	269396
3.5		15 m downstream of NE 141st St and 111th Ave NE	1305877	268152
4	27-363-E1186	open channel downstream of bridge S side of NE 140th St	1305835	267660
5	LL446	open channel upstream of culvert on 108th Ave NE	1304815	266480
6	446-6	open channel of S fork just upstream of confluence near 105th Ave NE	1304052	265823
7	CCC446	open channel of mainstream just below confluence near 105th Ave NE	1304004	265822
8	CC446	open channel NW of volleyball ct at Lakeside Recovery Center N of NE 132nd St	1303404	265607
9	C446	C446 main channel near RD pond W of 103rd Pl NE and S of NE 132nd St	1303185	265001
10	446-10	E side of bridge on 102nd Ln NE mid-channel	1302943	264915
11	446-11	sample W side of bridge 102nd Ln NE mid-channel	1302919	264878
12	446-12	off E side of bridge 101st Ln mid-channel	1302658	264657
13	446-13	bioswale if it has flow	1302606	264658
14	446-14	mid-channel below bioswale	1302516	264583
15	446-15	backwater in bend near large Doug fir	1302417	264438
16	446-16	mid-channel off footpath N of 17, N of NE 29th Pl	1302316	264364
17	RNA446HS	mid-channel below confluence N of NE 129th Pl	1302257	264296
18	446-18	mid-channel E side of bridge over 100th Ave NE	1302138	264148
19	446-19	mid-channel downstream of outfall from bridge	1302040	264102
20	A446	RD pond outfall if it has flow	1302041	264122
21	446-21	main channel S side of NE 128th St below outfall	1301914	263709
22	446-22	pond outfall W of 100th Ave NE	1301905	263685
23	446-23	along creek near viewing platform	1301886	263662
24	446-24	upstream of sewer line above confluence and LWD	1301737	262992
25	446-25	end of meander near lg cottonwood W/ treehouse	1301678	262931
26	446-26	mid-channel W side of stream	1301429	262698
28	446-28	N side of footbridge N of 124th St	1301462	262539
29	446-29	N side of bridge mid-channel N of NE 122nd St	1301457	261964
30	446-30	mid-channel at upstream of stream project	1301374	261693

Table 1 (continued)				
31	446-31	pipe outfall on E side of creek if flowing	1301345	261666
32	446-32	mid-channel near 3 air conditioners	1301313	261653
33	446-33	mid-channel E of driveway and S of NE 120th St	1300384	261191
34	446-34	mid-channel W side of culvert S of NE 120th St	1300314	261199
35	446-35	mid-channel off of N side of foot bridge	1299878	260578
36	446	mid-channel downstream of footbridge in Juanita Beach Park	1299836	260103
37	X446	pool just upstream of Lake Washington	1299542	259896
38	446-38	top of channel S of NE 124th St and W of 84th Ave NE W of trailer park	1299890	262483
39	446-39	trib flow from the N by sampling outfall E of driveway	1300367	261215
40	27-414-E2502	channel in meadow S of NE 134th St and E of 88th Pl NE, walk down bank past small trees	1298313	265769
42	446-42	mid-channel S of dead-end of NE 128th Ln	1299401	264138
43	446-43	channel W of 94th Ave NE and N of NE 126th Pl	1300085	263401
44	446-44	downstream of culvert, E of 94th Ave NE and S of NE 126th Pl	1300153	263292
45	446-45	follow footpath to outfall, sample outfall - flows year round (site Billy Creek) (misID'd as 27)	1301454	262512
46		W side of parking lot N of NE 132nd St	1300718	265185
	446-47	outfall S of NE 128thSt and W of 100th Ave NE	1301959	263853
47.5		upstream of 48 at 88th Ave NE and NE 145th St	1298194	270579
48	446-48	outfall of culvert from N, S of NE 144th St and E of 88th Ave NE (pump station construction site)	1298352	269734
49		outfall of culvert from W, S of NE 144th St and E of 88th Ave NE (construction site)	1298345	269708
50	446-50	upstream of culvert W of 100th Ave NE and S of Simmons Rd NE	1302096	269339
51	27-343-E1189	mid-channel S of NE 140th Pl and between 103rd Ave NE and NE 140th Pl	1303380	267884
52	RNA446NW	downstream of culvert on NE 137th Pl	1303879	266738
53	446-53	mid-channel of N trib	1304033	265849
54	446-54	E side of pond	1300128	271096
55	446-55	outfall pipe adjacent to 55 S of NE 140th Pl	1303391	267905
56	446-56	below retaining wall E of 112th Ave NE	1306285	273605
57	446-57	above pond outflow pipe	1306286	272218
58	446-58	below culvert in ditch SE of Juanita-Woodinville Rd and S of NE 149th St	1305992	271508
59	27-9005-P578	channel below outfall pipe N of main channel and locator 3 N of NE143rd Pl	1305467	269429
60	446-60	KC vault N of NE 140th St - requires hook to remove lid	1311512	267661
61	446-61	mid-channel below RD pond outfall, N of NE 134th Pl and E of 124th Ave NE	1310134	265952
62	446-62	upstream of Mickleson Ponds S of NE 132nd St	1308954	264896

Table 1 (continued)				
63	446-63	outfall of ponds S of NE 132nd St and E of 120th Ave NE	1308860	264600
64	446-64	ditch just above culvert in parking lot S of NE 132nd St and E of Totem Lake Blvd	1307438	264655
65	446-65	main channel E side of 114th Pl NE and N of NE132nd Ave, just above apt driveway	1306666	265380
65.5		downstream of RD pond NE 134thSt and 109th Ave NE at outfall pipe under road	1305129	265960
66	TEMP	just above culvert under 108th Ave NE	1304807	266255
67	446-67	pond on S side	1306101	265938
68	A3019	outfall at N end of Big O Tires behind garbage container N of NE124th St	1310610	261984
69	446-69	ditch in Totem Lake Commerce Center parking lot below culvert	1311358	262659
70	446-70	hike up gravel path to outflow vault on N side of parking lot, tool and key required	1311183	263269
71	446-71	Totem Lake from end of boardwalk, park at Yuppie Pawn	1309952	262438
72	446-72	square manhole lid 40' E of Bank of America, N side of Totem Lake Blvd	1309289	262009
73	446-73	RD pond inside I-405 on ramp SW of Totem Lake Blvd and NE of NE 124th St	1308860	261979
74	446-74	channel at Verizon Parking Lot near culvert	1308307	262377
75	446-75	W side of bridge W of 116th Ave NE	1307266	263088
76	446-76	mid channel downstream of E most driveway of Tanager Apt off 128th St	1306605	263186
78		outfall NE of corner of NE 125th Pl and 107th PL NE	1304630	263193
79	F446	N side of footbridge off center field of HS baseball diamond	1303716	263192
80	446-80	downstream of culvert W of 103rd Pl NE	1303002	263894
81	D446	tributary on N side of NE 129th Pl and E of 100th Ave NE	1302389	264305
83	446-83	manhole on N side of NE 124th St at crosswalk	1304661	262448
84	446-84	outlet of pond E of 100th Ave and S of NE 126th Ln	1302143	263003
85	446-85	manhole W of 99th Ave, E of Lake Washington, NE and S of NE 116th St	1301452	259150
86	446-86	outflow of pipe W of 99th Ave E	1301059	259379
87	0806ESB	eastern third of swimming area 0806ESB	1300418	259655
88	0806SB	center of swimming area 0806SB	1300256	259749
89	0806WSB	west third of swimming area 0806WSB	1300106	259813

Assumptions Underlying the Design

This study assumes that the bacterial pollution at the beach and in the creek are from a combination of non-point sources and unidentified point sources. For the purposes of this study, non-point sources are diffuse sources of contamination such as pet waste from urban areas or waste from wildlife such as birds and beavers. Types of point sources suspected of adding to fecal contamination in this study include failing septic systems, cross-connections between the sanitary sewer and the stormwater system, and specific instances of dumping or discharge of pollutants.

To meet water quality criteria for fecal coliform both the non-point sources and the unidentified sources need to be found and corrected. The current study design sampled from the headwaters of the tributaries to the mouth of the stream, and assumed that differences between upstream and downstream bacteria counts will identify short segments containing sources or sinks of bacterial pollution in the watershed. By identifying short stream segments that contain bacteria source(s), the probability of locating and subsequently correcting specific pollution sources is much higher than it would be without this density of sampling. Bacterial sources are typically temporary, episodic and variable. By sampling twice each sampling event and conducting three monthly sampling events, the likelihood of detecting these potentially transitory sources is increased. By minimizing the length of stream segments as much as possible by multiple sampling sites the likelihood of locating bacterial sources is increases by reducing the area to search for sources. If the source(s) are chronic, this should be observed in consistently elevated counts in the data. Episodic sources should be detected by observing differences between AM and PM sampling. It is unlikely that all episodic events will occur during the sampling period of this study making their control even more difficult. The efficacy of this study design can only be determined by the number of currently unidentified bacterial sources that are located.

Sampling Locations and Frequencies at Each Location

Sampling sites were defined first as a geographic information system (GIS) exercise using data layers for the Juanita Creek watershed, including stream network, watershed boundary, topography, property parcels and land cover/land use data layers. All of the GIS data layers and associated metadata is contained in Appendix A, and an electronic copy of these files is attached to this report. Using the GIS files initial sample sites were selected to segment the mainstem and tributaries of Juanita Creek into relatively short stream segments, and to isolate specific land uses. Sites were located as close to the headwaters of all of the tributaries as possible, at the lowest accessible sections of each tributary and downstream of confluences and at the swimming beach in Lake Washington. Any stormwater facilities or drainage ditches within the watershed were identified for sampling as well. The initial numbering of sample sites was sequential starting at the headwaters to the mouth of the mainstem, and then continuing in the sampled tributaries from the west side of the basin to the east (Figure 4).

All GIS selected sampling sites were field verified for accessibility. Sites were located on public property where possible to minimize the need to coordinate permission and access to private property, but when sites were only accessible from private property, written permission to sample was obtained from the owner.

Maximizing the number of samples was designed to minimize the length of stream segments responding to potential bacterial sources, and decrease as much as possible the size of the segment defined sub-basin areas necessary to search in Phase II to specifically locate bacterial sources. Conversely, areas of the watershed that have consistently low bacteria counts can be removed from the search area.

The total number of samples per event was set by the analytical capacity of the KCEL to process the samples (filtration and incubation capacity primarily) and the capacity of the available field crews to collect the samples and transport them to the KCEL (around 15 miles) within the holding time. Holding time for the samples was 24 hours and held on ice, although all samples were analyzed well before the 24 hour holding times expired. The maximum number of samples was also constrained by the number of sampling locations that could be safely sampled within an approximately four hour period (to allow for two sampling of each location on each sampling day). Selection of sampling locations was also constrained by safety and time to access particular locations and permission by property owners to sample on private property.

Sampling Protocol

Single grab samples for fecal coliform were collected at each sampling location for the three sampling runs. At stream segments that had minimal flow or inaccessible flow from stream bank, a sampling pole with a 500 ml bottle holder was used to collect the grab sample. Single grab samples for *E.coli* were collected at the same time from City of Kirkland Juanita Creek *E.coli* monitoring sites 16, 17, 27, 33, 34, 39 and 81, with a sampling pole and dip cup for side-by-side comparison testing. No samples were collected from dry stream segments, and lack of flow was noted on the field sheets. Field replicates were collected for ten percent of samples collected.

Four field crews of two individuals were assigned to sample a predetermined subset of sampling locations, based on overall time to sample and driving time between sampling locations. Sample bottles were pre-washed and labeled sample bottles were organized and allocated accordingly. Field data sheets with the same lab sample numbers as the sample bottles were provided in order to collect narrative information and conventional data from the multiprobes. All field crews were required to rendezvous at Juanita Park with the AM set of samples for transport to KCEL to meet fecal coliform holding times, provide the necessary physical space in the vehicles, and restock with pre-washed labeled bottles to collect the PM sets samples. This two phase delivery of samples to KCEL allowed sufficient time to filter the AM samples in the microbiology laboratory prior to the PM set of samples arriving in the evening, maximizing the capacity of the laboratory.

To provide an estimate of diel temporal variability, bacteria data was collected at every sampling location twice each sampling day. Three AM-PM sampling events of all sites were conducted. July and August samplings events were originally designed to target the typical summer low flow period, and the third sampling event in October was to sample the first large rainfall event of the typical rainy season in autumn. However, while a dry weather low flow event was sampled on July 30, the sampling on August 27 happened to coincide with the first substantial rain of the late summer, and can be considered the best approximation of a ‘first flush’ sampling. The September 24 event was also during a rainfall event (Table 1). It was not logistically possible to reschedule either the August or September sampling events to a dry low flow period due to the logistical constraints.

Conventional parameters (temperature, pH, dissolved oxygen, conductivity) were measured once each sampling day at every sampling location using calibrated multiprobes following the KCEL Standard Operating procedure (SOP) #205v4 Field Measurements using an Attended Hydrolab. Conventionals were sampled during either the AM of PM runs, but not both runs due to the limited availability of multiprobes (two) for this study. Each multiprobe was checked for calibration by KCEL during the noon sample pick up at Juanita Park.

Data Analysis

Stream segments that were identified as potential source of bacteria (large increases between the upstream and downstream sampling location) had additional sample locations established bisecting the segment to decrease the length of the stream segments to reduce the length of the stream segment with the input of bacteria. Visual surveys of the identified stream segment with an analysis of storm drains, septic fields, and sanitary sewer lines will be carried out to locate sources (and begin corrective actions to eliminate the bacterial source in phase II). Bacterial counts of all stream segments are represented on a GIS layer, and are used to focus bacterial source identification and control efforts. All information on the bacteria counts and geographic extent of the suspect stream segments will be shared with PHS&KC for evaluation of potential human health risk.

The data set will be analyzed post-facto to evaluate potential sampling design for urban watersheds with bacteria pollution issues. Post sampling analysis of the data will analyze the power and sample size that would have been the most effective design to evaluate the Juanita watershed, or provide insight to the feasibility of this approach. This analysis will be available to optimize future sampling designs in other watersheds.

While it is important to examine the link between flow and fecal coliform to calculate wasteload allocations and development of TMDLs, for the source identification portion of this project bacterial counts were used as an indicator of bacterial pollution to the stream. If a TMDL is to be developed in this basin, flows will be necessary to develop load and wasteload allocations for sources, and it would be necessary to either significantly increase the field staff collecting data or drastically reduce the number of samples collected.

This project is designed to support the location of fecal coliform bacteria sources so they can be corrected. Had flows been calculated for each sampling site in this study, the time to collect both the samples and flow data would have necessitated a large reduction in the number of samples collected. A reduction in the number of samples would have increased the delineation of the suspect stream segments and drainage areas making source location more difficult.

Results and Discussion

Juanita Creek exceeds water quality criteria for fecal coliform bacteria far more frequently than it meets the criteria (Figure 5; Table 2). The 2008 King County monthly monitoring data for both routine monitoring sites, O446 and C446, were > 50 cfu/100ml 100% of the time and >200cfu/100ml over 90% of time. Both of these sampling locations were included in the current study, allowing a comparison of the data collected at these two sites with the overall geometric mean for all samples collected during each sampling event (Table 3). Of the six sampling events in this study, fecal coliform bacteria at O446 was slightly higher than the whole basin geometric mean, while the bacteria counts at C446 was often greater than twice that of the whole basin geometric means. This is not unexpected because basin-wide sampling in this study included headwater sites selected to provide background bacteria counts before flowing through developed areas. While both routine King County monitoring sites are in the lower developed portion of the stream and potentially overestimates the bacterial counts compared to this sample set, these routine sites accurately identified that bacteria in this stream does not meet criteria. The routine King County monitoring program is sufficient to identify pollution problems at the basin scale. The current study confirms that bacterial pollution in the Juanita watershed is wide-spread, variable, and often episodic or transitory.

Very few of the Juanita basin sampling locations met the *WAC173-201A* water quality criteria of 50 cfu/100ml for extraordinary primary contact on any of the sampling days (Table 3). During the July dry season sampling only 23% of the morning sampled sites (AM) and 18% of the afternoon sampled sites (PM) met the criteria. The percent meeting the criteria in August was 8% AM and only 2% PM. On September 20, 21% AM and 27% PM locations met the criteria.

The August sampling event occurred during the first substantial rain event of the season and can be considered as a 'first-flush' sampling event, and may account for the higher levels of exceedances. The overall impact of the August 27 rain event can be seen comparing the geometric means of all sites for the three sampling dates (Table 2 and 3; Figure 5). The geometric means for the August sampling events were nearly twice the means of the other sampling events, and the percent of samples meeting the water quality criteria were less than half that of samples collected at either the July or September sampling events. The higher August counts were primarily in the mainstem and during both the AM and PM sampling runs, but several of the PM samples were much higher than any other sampling events in the mainstem. The September sampling event was also a rain sampling, but the bacteria samples that exceeded the criteria were less than during the first storm event sampled in August

These findings are somewhat counter to what was observed in 1994 in North Creek, Snohomish County WA, where they observed fecal coliform levels significantly higher during the dry season than during the wet season, which they attributed to low flows and little dilution (Ecology 2002). Geometric means for bacteria were much higher during the first rain of the season than either during the dry sampling or during a later wet season storm. While individual sites were high in July and probably influenced by low flows and a lack of dilution, the August sampling event serendipitously, captured the first rain event after the dry summer.

Table 2. Juanita Creek fecal coliform bacteria data collected July 30, August 27, and September 24, 2008. All counts in cfu/100ml.

	July 30		August 27		September 24		geometric	maximum	n	
ID #	AM	PM	AM	PM	AM	PM	mean			
	Juanita Creek Mainstem									
1	9	13	260	305	410	350	105	410	6	
2	33	30	250	2700	153	55	133	2700	6	
2.1					23			23	1	pipe
3	125	200	260	6900	49	47	217	6900	6	
3.5			750	940	770	840	822	940	4	
4	1800	2500	1800	3300	500	1035	1549	3300	6	
5	1200	810	700	2300	550	750	930	2300	6	
6	3000	870	1000	3400	760	550	1244	3400	6	
7	1400	780	1100	3500	760	500	1081	3500	6	
8	760	550	920	960	640	470	693	960	6	
9	680		1000	1600	430	435	727	1600	5	C446
10	710	470	1600	1200	550	330	699	1600	6	
11	505	550	795	1800	480	430	659	1800	6	
12	690	510	2200	2400	540	230	783	2400	6	
13			120					120	1	bioswale
14	710	460	1100	725	290	280	526	1100	6	
15	660	1700	1115	800	360	370	715	1700	6	
16	660	470	900	700	335	450	556	900	6	
17	400	410	720	620	160	190	361	720	6	
18	240	350	570	530	170	360	340	570	6	
19	580	460	565	630	63	240	336	630	6	
20	40	60	730	2300	270	100	218	2300	6	Pond?
21	4	4	710	510	280	310	89	710	6	
22	520				68	52	123	520	3	
23	560	560	540	540	390	200	439	560	6	
24	450	290	580	520	390	190	378	580	6	
25	450	355	560	540	260	160	355	560	6	
26	420	290	700	550	350	320	417	700	6	
28	550	350	420	620	305	250	395	620	6	
29	460	390	650	525	280	145	368	650	6	
30	460	280	560	620	180	210	345	620	6	
31			800	660	260	170	391	800	4	pipe
32	530	400	420	460	250	270	375	530	6	
33	380	375	490	540	270	230	364	540	6	
34	330	100	620	560	230	340	310	620	6	
35	460	250	560	400	240	260	342	560	6	
36	390	150	560	460	220	280	312	560	6	O446
37	430	130	860	670	250	230	350	860	6	

Table 2 (continued)										
	July 30		August 27		September 24		geometric mean	maximum	n	
ID #	AM	PM	AM	PM	AM	PM				
				Tributary A						
38	230	110	110	450	26	21	94	450	6	
39	82	67	330	270	470	410	213	470	6	
				Billy Creek						
40	5	10	1700	710	1800	800	210	1800	6	
42	100	60	61	60	25	26	49	100	6	
43	680	59	120	150	190	52	139	680	6	
44	700	530	110	120	600	51	230	700	6	
45	570	420	190	160	90	78	193	570	6	
				Tributary B						
47	480	430	62	100	6	2	50	480	6	
				West Fork Juanita Creek						
47.5			2800			2000		2800	2	
48	1900	860	1300	2200	790	815	1202	2200	6	
49	350	250	160	210	220	89	196	350	6	
50	310	78	470	600	260	230	272	600	6	
51	1000	770	810	720	1700	710	903	1700	6	
52	470	360	860	670	590	990	620	990	6	
53	660	560	790	480	790	400	595	790	6	
54	260	160	510	380	76	73	188	510	6	
55	9	1	220	400	2	5	14	400	6	pipe
				North Fork Juanita Creek						
56	15	3			66	37	18	66	4	
57	37	260	46	280	19	10	54	280	6	pond
58	880	770	500	540	4800	4400	1253	4800	6	
59	410	210	330	550	2000	1200	579	2000	6	
				Kingsgate Tributary						
60	1	1	170	310	7	4	11	310	6	vault
61	420	5	240	350	42	35	80	420	6	
62	38	23	35	48	70	80	45	80	6	
63	94	54	750	660	200	81	185	750	6	pond
64	75	52	350	800	160	95	160	800	6	
65	63	65	240	500	54	35	99	500	6	
65.5			2100	1400	2200	800	1508	2200	4	pond
66	1200	950	935	770	1500	910	1019	1500	6	

Table 2. (continued)									
	July 30		August 27		September 24		geometric mean	maximum	n
ID #	AM	PM	AM	PM	AM	PM			
				Totem Creek					
67	460	4100	370	120	190	110	347	4100	6
68	9	70	200	240	21	30	52	240	6
69	460	810	280	210	36000	5600	1281	36000	6
70			230	430	40	17	91	430	4
71	4	1	10	58	58	35	13	58	6
72	1700	1000	280	300	42	48	257	1700	6
73	5	4	22	47	5	6	9	47	6
74	40	60	140	190	53	37	71	190	6
75	100	360	34	130	17	18	60	360	6
76	57	85	28	60	54	270	70	270	6
77			160	160			160	160	2
79	110	93	300	460	290	59	170	460	6
80	78	52	350	470	180	240	175	470	6
81	69	54	400	360	71	100	125	400	6
83	1	5	260	400	1100	1800	100	1800	6
				RD pond at 100th Ave and NE 126th Ln					
84	71	63	400	200	7	6	50	400	6
				Tributary S					
85	450	120	200	280	280	120	216	450	6
86	1800	28000	580	670	160	220	940	28000	6
				Juanita swimming beach					
87	510	160	1100	560	170	970	450	1100	6
88	86	93	510	560	440	1200	326	1200	6
89	59	92	520	540	860	840	321	860	6

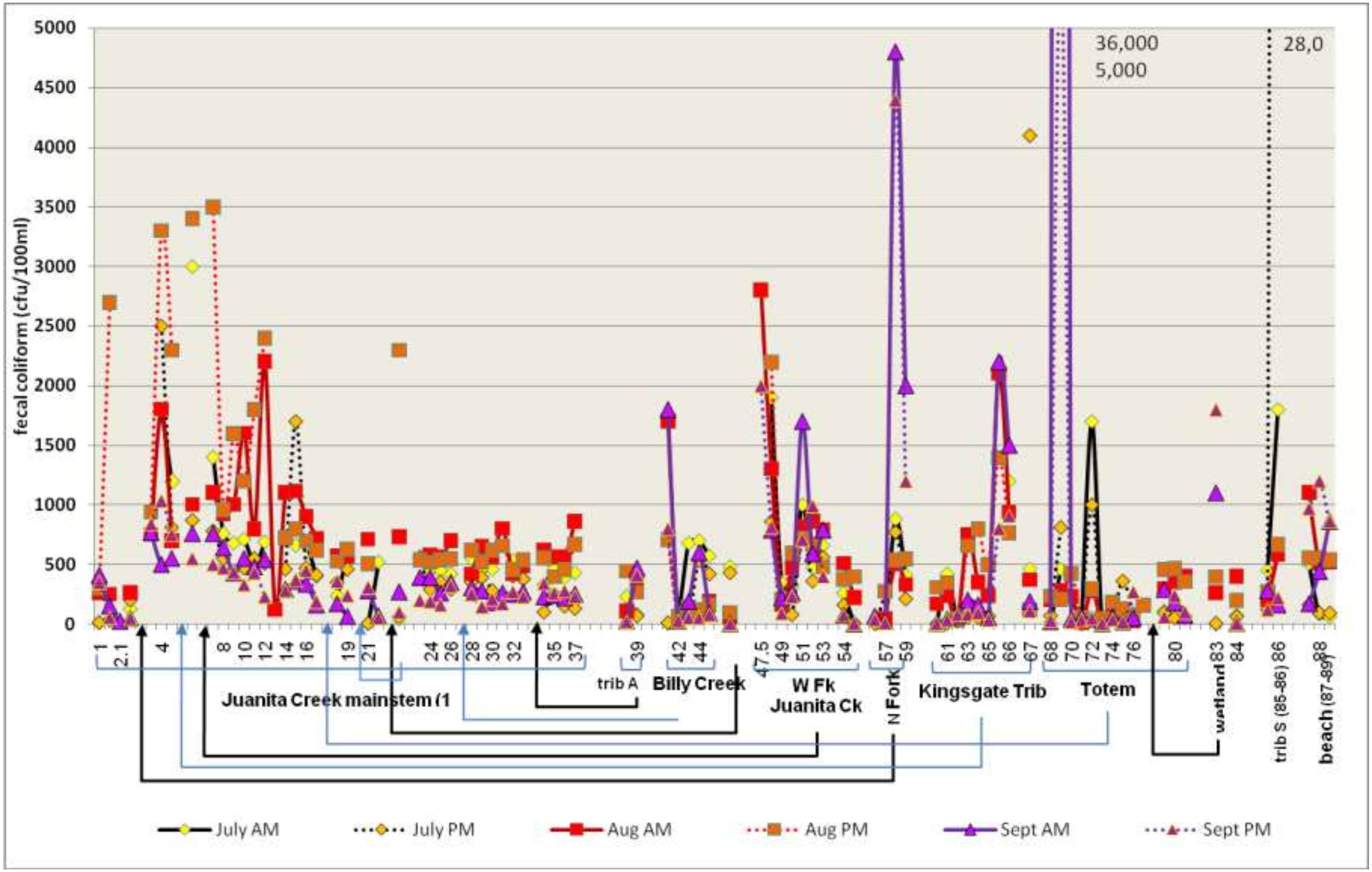


Figure 5. Fecal coliform bacteria (cfu/100ml) collected at all sampling sites in the morning (AM) and afternoon (PM) on July 30, August 27 and September 24, 2008. Arrows at the bottom of the graph indicate where the tributary streams enter the mainstem of Juanita Creek.

Comparing bacteria counts collected almost a month apart and attributing the differences to the 'first-flush' may not be seen as a strong argument, but two additional observations support the contention that the August sampling captured the first flush event in the Juanita watershed; the increased bacteria counts occurred at all sites in the mainstem, and at a majority of the site in the tributaries, and both the August AM and PM samples were elevated. On August 27, the majority of the PM samples were greater than the AM samples responding to the day long rains.

The response of nearly all sampling sites having higher bacteria counts on August 27 indicates a strong non-point bacterial source. Wash off of fecal material accumulated in the watershed during the preceding dry period would account for bacterial increases at nearly all of the sampling sites.

Table 3. Percent of Juanita fecal coliform bacteria data that meet WAC173-201A bacteria criteria.

	July 30		August 27		September 24		total data set
	AM	PM	AM	PM	AM	PM	
geometric mean all sample sites	**193**	**149**	**384**	**488**	**191**	**165**	
n	80	78	85	83	85	85	
long-term sites							
O446	390	150	560	460	220	280	
C446	680		1000	1600	430	435	
count below 50 cfu/100ml	15	12	6	2	15	18	9
count above 50 cfu/100ml	65	66	79	81	70	67	76
% meeting extraordinary primary contact	**19**	**15**	**7**	**2**	**18**	**21**	**12**
count below 100 cfu/100ml	25	29	8	5	26	29	19
count above 100 cfu/100ml	46	73	73	55	50	62	78
% meeting primary contact	**35**	**28**	**10**	**8**	**34**	**32**	**24**
count below 200 cfu/100ml	29	36	17	13	36	38	33
count above 200 cfu/100ml	51	41	66	69	48	46	52
% meeting secondary contact	**36**	**47**	**20**	**16**	**43**	**45**	**63**
minimum	1	1	10	47	2	2	
maximum	3000	28000	2800	6900	36000	5600	

The bacteria counts from the September 20 sampling event were lower than counts collected on August 27 and were most likely due to the accumulated dry season non-point pollutants having already been washed off of many of the surfaces in the watershed by the previous rain. The high counts at sites that did not occur in August also seem to be associated with episodic events. Many of these episodic events either had AM or PM samples much different from one another, or were observed at the particular sampling site only once during the three month sampling period.

Pollution sources, whether point or non-point sources, cause changes in multiple water quality parameters and at times can be used to identify potential sources. Conventional water quality data for temperature (Figure 6), dissolved oxygen (Figure 7), conductivity (Figure 8), and pH (Figure 9) was collected synoptically with a subset of the bacterial samples. Comparison of these parameters on each sampling event is possible, but sampling capacity only allowed each site to be sampled once per sampling event (as compared to the AM and PM bacteria sampling), precluding any AM – PM parameter evaluation.

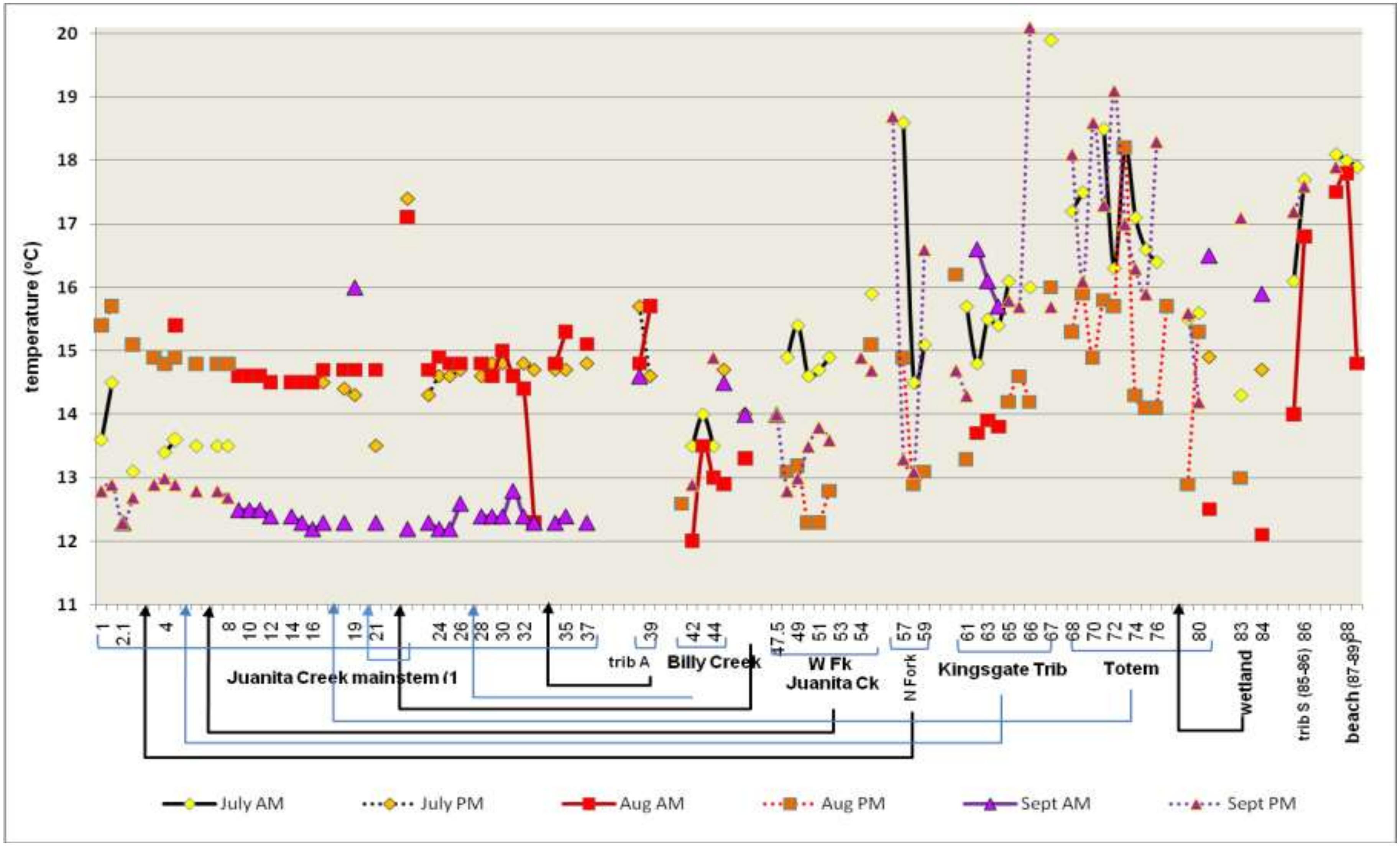


Figure 6. Temperature (°C) collected at sampling sites either in the morning (AM) and afternoon (PM) on July 30, August 27 and September 24, 2008. Arrows at the bottom of the graph indicate where the tributary streams enter the mainstem of Juanita Creek.

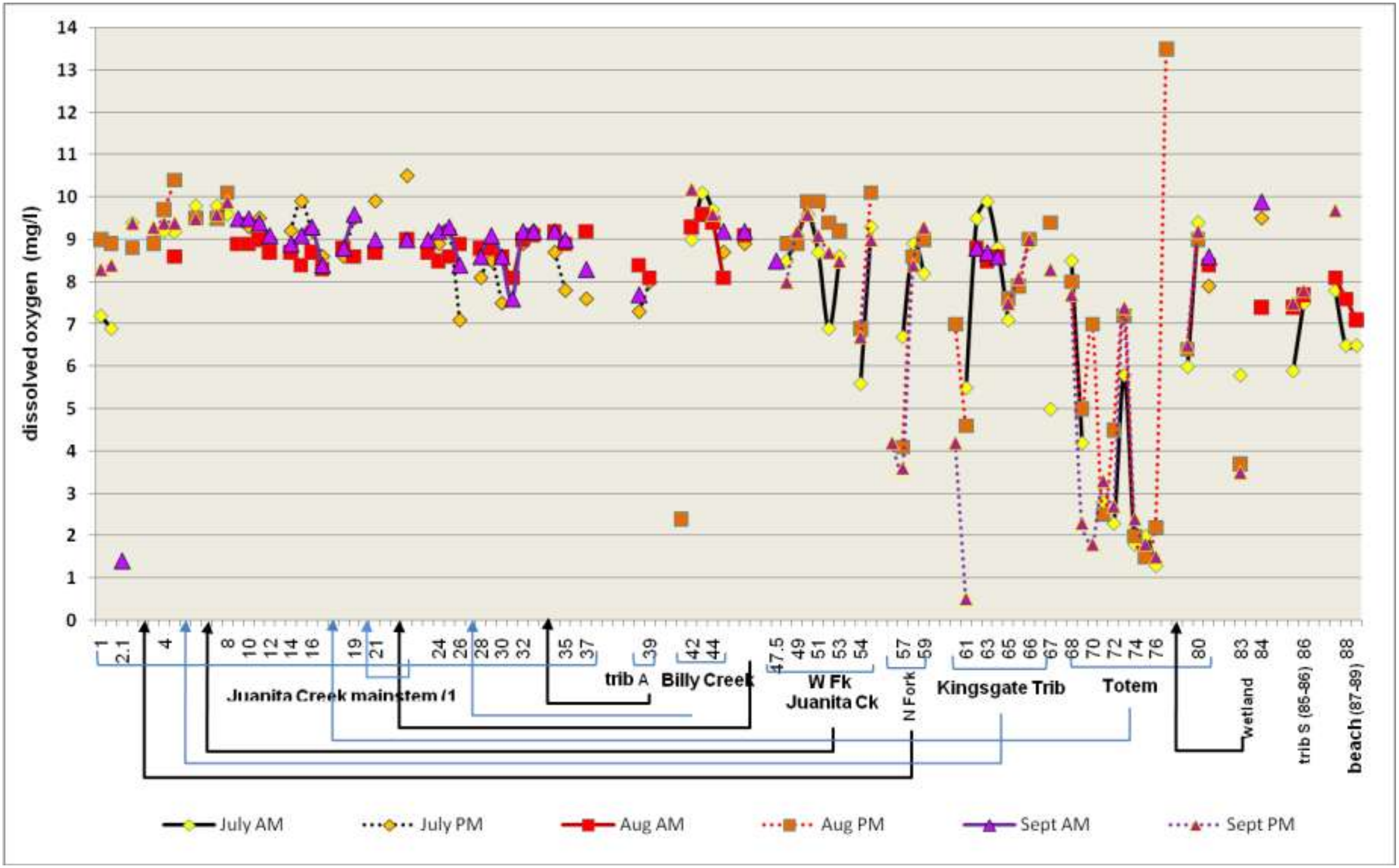


Figure 7. Dissolved oxygen (mg/l) collected at sampling sites either in the morning (AM) and afternoon (PM) on July 30, August 27 and September 24, 2008. Arrows at the bottom of the graph indicate where the tributary streams enter the mainstem of Juanita Creek.

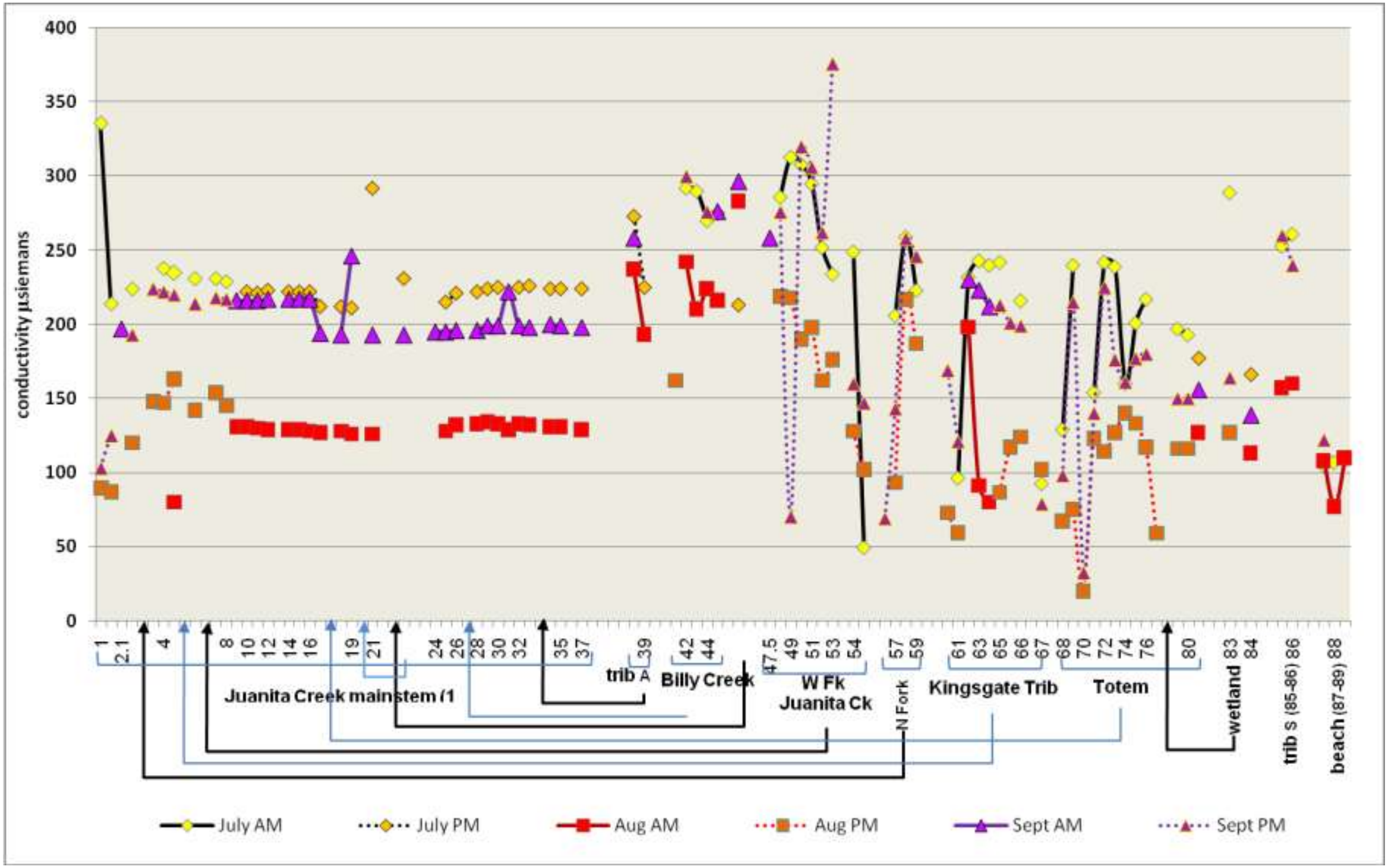


Figure 8. Conductivity (µsiemans) collected at sampling sites either in the morning (AM) and afternoon (PM) on July 30, August 27 and September 24, 2008. Arrows at the bottom of the graph indicate where the tributary streams enter the mainstem of Juanita Creek.

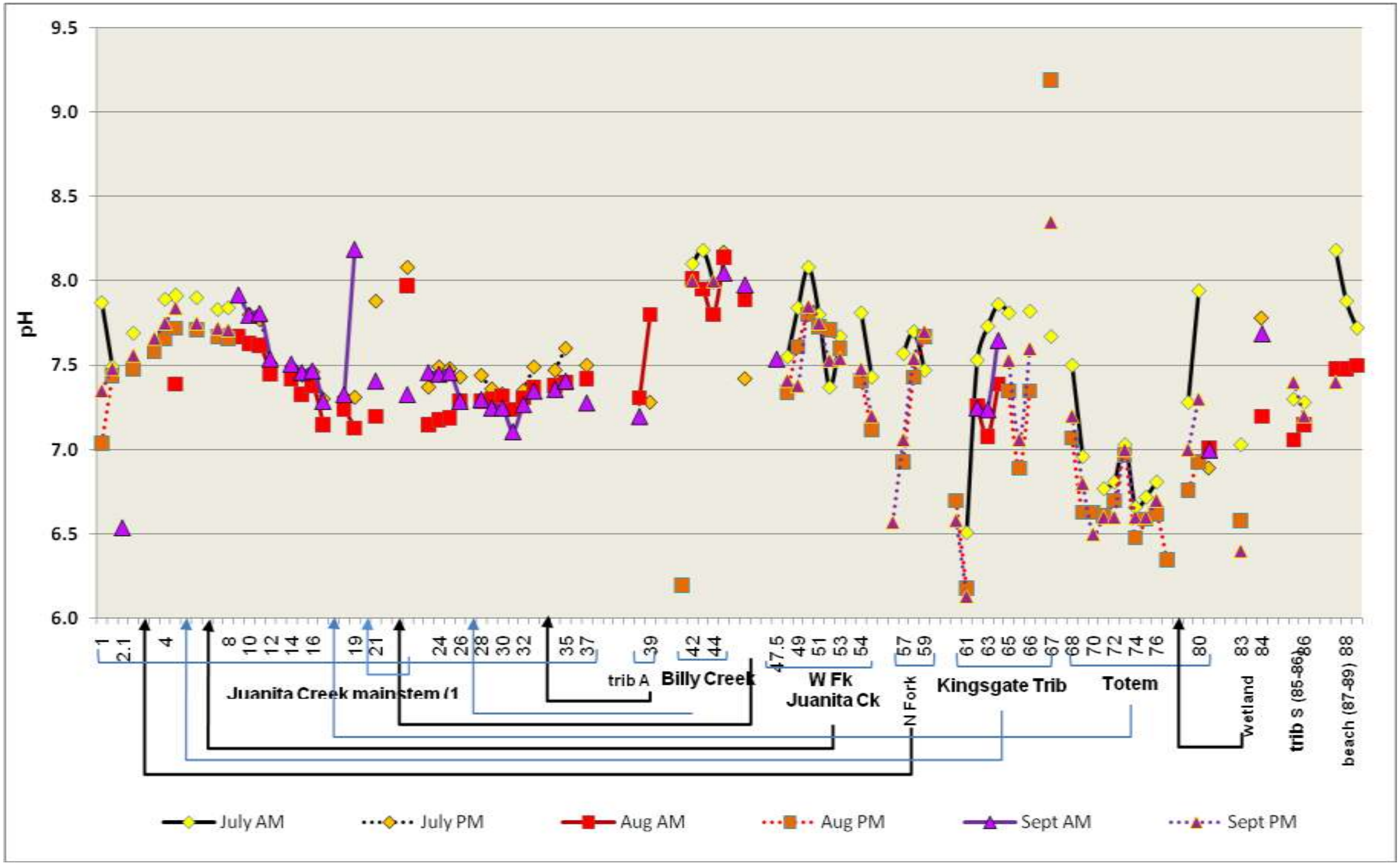


Figure 9.pH collected at sampling sites either in the morning (AM) and afternoon (PM) on July 30, August 27 and September 24, 2008. Arrows at the bottom of the graph indicate where the tributary streams enter the mainstem of Juanita Creek.

Patterns of bacterial pollution in Juanita Creek

Mainstem Juanita Creek

The general pattern for fecal coliform in the mainstem of Juanita Creek was relatively low bacteria counts in the headwaters (sites 1-3 in unincorporated King County) compared to the rest of the basin. Sites 1 and 2 were among the few sites in the basin to actually meet the 50 cfu/100 ml criteria during July (Table 2, Figure 5). Site 1 had low values in July (9, 13), but in August (260, 305) and September (410, 350) counts from the rain events exceeded criteria. This site drains single family residences. A notable exception to the relatively low bacteria counts in this section of the creek was the August PM sample (site 2 AM 250 cfu/100ml PM 2700 cfu/100ml). Site 2, located in a wooded park-like area immediately east of I-405 is popular with dog-walkers and receives wash-off from an area of predominantly single family residences. Pet waste could be a possible source of the high August PM sample, not only at this site, but watershed wide. Because of the high counts at site 2 in August and the presence of turbid water from the adjacent storm drain (site 2.1) was added to the September sampling event. However, the bacteria count from this drain in September was very low (23 cfu/100ml), as were the bacteria counts basin wide. An increased bacteria count on August 27 PM was also seen immediately downstream at site 3, which went from AM 260 cfu/100ml to PM 6900 cfu/100ml (Table 2, Figure 5). Site 3 potentially receives some wash-off from I-405.

The most noticeable and consistent increase in bacteria along the mainstem occurred between sites 3- and 4. Elevated counts in this section of the stream apparently contribute to the elevated counts through the middle section of the creek to just above the confluence with the Totem Creek. The lower section of the mainstem (sites 18-37) had fairly consistent counts (Table 2 and 4).

Table 4. Fecal coliform geometric means for the upper, middle and lower portions of the mainstem of Juanita Creek.

Juanita mainstem sites	July 30		August 27		September 24	
	AM	PM	AM	PM	AM	PM
upper (1 -3)	33	43	257	1784	92	97
middle (3.5 - 17)	861	705	1055	1443	472	441
lower (18-37)	335	220	587	544	226	218

Below the confluence with the North Fork (site 3 is immediately upstream of the confluence), the bacteria counts in the mainstem were much higher, and elevated counts in this section of the stream apparently elevated the bacteria counts in the lower portions of the mainstem inside the City of Kirkland all the way to the mouth of the stream at Lake Washington.

The middle section of the mainstem tended to decrease downstream in both July and September, and counts were relatively consistent when compared to changes observed in the upper portion or the tributaries. In the middle stretch of the mainstem, August counts increased between sites 7-12, and then were relatively consistent to the lake. August counts in the middle section of the mainstem were higher than either the dry season July samples or subsequent rainy samples in September.

The range of bacteria counts in the mainstem and the differences between AM and PM samples was highest during the August 'first flush' event. In contrast, tributary streams were much more variable in September when the mainstem was far less variable. Due to the influence of high bacteria counts flowing downstream from the middle portion of the mainstem (in unincorporated King County), it is more difficult to discern potential sources by measuring changes in bacteria counts in the lower portions of the mainstem of the creek.

North Fork

The North Fork (sites 56-59) starts in wooded open space and wetlands near the Tolt aqueduct. Site 56 is the furthermost headwater site in the study with drainage from areas that are relatively undeveloped and primarily in the Tolt pipeline easement. The headwater site had very low flows (<1 cfm) and very low bacteria counts (Table 5, Figure 5). This level of bacteria could be considered as the headwater baseline for the creek. The low bacteria counts in this fork increased between the RD pond (site 57) and site 58 along Juanita Woodinville Road. There was nothing obvious to indicate why there should be an increase in bacterial loading in this area (no change in turbidity, flow, or color), as the steam runs in a channelized stretch along the roadway and drains a primarily single family residence area. Ditch maintenance was conducted on the south side of the road near the park and ride lot, but during the study no flow from this area was observed.

The flow path from the stream along the road to where it discharges into the mainstem just below the pedestrian bridge in Winsor Vista Park is not correct in the KC GIS layer. The stream disappears into a culvert and when it reappears from the pipe in the park the flows appear to be lower than what goes into the pipe. This area needs further investigation to define the flow path and the source of bacteria, detailed mapping will be carried out in Phase II.

The highest counts in the North Fork were sampled in September at site 58 and were the second highest sample pair collected during that event. Again, no obvious source was observed and this area should be targeted for further investigation in Phase II.

Table 5. Fecal coliform bacteria counts (cfu/100ml) for sites in the North Fork of Juanita Creek.

	July 30		August 27		September 24	
North Fork sites	AM	PM	AM	PM	AM	PM
56	15	3			66	37
57	37	260	46	280	19	10
58	880	770	500	540	4800	4400
59	410	210	330	550	2000	1200

West Fork

The West Fork of Juanita Creek (sites 47.5 -53) starts near Inglemoor High School and flows through an area of blackberries and single family residences before flowing through a wooded canyon along Simmonds Road down to 100th Ave NE (site 50). From site 50 to the confluence with the mainstem at site 53 the stream runs through a large single family residences between 100th Ave NE and Juanita Woodinville Road. During the study the sewer pump station at 90th St was being reconstructed immediately upstream of locators 49 and 48. These sites had very low flows throughout the study. Site 48 along the north branch had brown foam on the surface and had the second highest count in the watershed on the July AM sample (1900). The PM sample was not as high. To determine whether the pump station construction was a potential bacteria source, an additional sampling site was established upstream at NE 145th St (site 47.5) and sampled once in August AM (2800) and once in September PM (2000), both samples were greater than the downstream counts at 48, apparently eliminating the construction site as the bacteria source in this headwater tributary, and moving the potential source upstream of NE 145th Street. Generally, counts tended to decrease through the canyon south of Simmonds Road to site 50 at 100th Ave NE, where counts increased as the stream passed through the housing development from 100th Ave NE to near Juanita Woodinville Road. There a storm drain (site 55) from the neighborhood to the northeast discharged into the creek. The bacteria counts in this storm drain had some of the consistently lowest counts in the basin, and probably dilute the counts further downstream along the West Fork (52-53).

Table 6. Fecal coliform bacteria counts (cfu/100ml) for sites in the West Fork of Juanita Creek.

		July 30		August 27		September 24	
West Fork sites		AM	PM	AM	PM	AM	PM
	47.5			2800			2000
	48	1900	860	1300	2200	790	815
	49	350	250	160	210	220	89
	50	310	78	470	600	260	230
	51	1000	770	810	720	1700	710
	52	470	360	860	670	590	990
	53	660	560	790	480	790	400
Pond	54	260	160	510	380	76	73
Stormdrain	55	9	1	220	400	2	5

Kingsgate Tributary

The Kingsgate Tributary basin is mostly east of I-405, draining areas of predominantly single and multifamily residences with some commercial areas. While the upper portions are identified on the King County streams layers as surface waters, the channel is entirely piped until south of 137th Pl NE. This upper portion of the tributary had very low flow during the entire study. Site 60 was a King County stormwater vault, and we were unable to determine where this water discharged. Bacterial counts in the vault were extremely low and the water was clear, and only exceeded the criteria during the August sampling when the water was also turbid. The turbidity was traced to cell phone construction activities near Kamiakin Jr High School uphill from the vault. Site 61 was the uppermost surface sample collected and had negligible flow on every sampling event with shallow standing water, which makes the bacteria counts at this site less reliable or comparable with the lower portions of the stream. Site 62 at the inflow to the Mickelson RD pond at NE 132nd St. was the upper most consistently flowing section of this tributary. The bacteria counts in the outflow from the pond (site 63) were higher than the bacteria counts in the pond inflow at every sampling event, most notably during the August sampling event. However, by September the difference between the inflow and outflow was negligible, and perhaps the pond had been flushed by the preceding rains. There were small decreases in bacterial counts between sites 63 and site 65 on the west side of I-405. An ornamental pond in the Totem Lake Apartment complex (site 67) was only connected to the creek through an overflow pipe. In July, the pond surface was below the level of the overflow pipe. The high bacteria count at site 67 in July was associated with a cyanobacteria bloom occurring in this pond during this sampling event.

Near the mouth of the Kingsgate tributary (site 66) the July counts were high and the water had a grey-blue tint often observed when sewage or grey water is in the surface water. Sewer lines were recently installed in this area but very few houses were connected at the time of this survey according to NUD records. An additional sample site (65.5) was added for August and September immediately downstream of 109th Ave NE, in the outflow of an in-stream detention pond. This pond was nearly empty in July with the stream running along the unvegetated bottom of the pond. During the August sampling event the pond was full and the bacteria counts were high, increasing by an order of magnitude between sites 65 and 65.5. There was a waterline replacement project in the vicinity of the stream during the study and the construction workers indicated that there would also be sewer line work in the area. The bacteria count increase along this stream segment was even greater during the September sampling. The area that drains to this retention pond and below site 65 should be an area of focus for Phase II.

Table 7. Fecal coliform bacteria counts (cfu/100ml) for sites in the Kingsgate Tributary of Juanita Creek.

		July 30		August 27		September 24	
Kingsgate Trib.		AM	PM	AM	PM	AM	PM
vault	60	1	1	170	310	7	4
	61	420	5	240	350	42	35
	62	38	23	35	48	70	80
	63	94	54	750	660	200	81
	64	75	52	350	800	160	95
	65	63	65	240	500	54	35
	65.5			2100	1400	2200	800
	66	1200	950	935	770	1500	910
pond	67	460	4100	370	120	190	110

Totem Creek

Upper Totem Creek drains an area of light industrial and commercial near NE 124th St and I-405. The middle section of the stream flows through an extensive wetland east of Juanita High School and enters the mainstem between sites 17 and 18. The upper portion of this creek has complicated drainage and most of the channel is in storm drains. Totem Lake (site 71) would meet the criteria used for public swimming beaches.

Three sites (69, 72 and 83) had bacteria counts on one of the three sampling dates so far above the counts collected during the other sampling events that there is a very high probability that these bacterial samples were collected during sanitary overflow events. All three of these sites are in the fully developed, paved, and piped upper portion of the watershed where there is little possibility that non-point sources could contribute these high counts. Furthermore, the high counts occurred only on one of the sampling days, with the other sampling events having counts orders of magnitude lower than the high count events. The lack of open channels draining to these sites makes sanitary overflow a probable source of this pollution, and increases the potential health risks of the high bacteria. The commercial areas that drain to these sites should be investigated by Public Health Seattle King County to identify and correct what is causing these episodic pollution events, and these areas should be the first area investigated in Phase II.

Table 8. Fecal coliform bacteria counts (cfu/100ml) for sites in Totem Creek.

		July 30		August 27		September 24	
Totem Creek sites		AM	PM	AM	PM	AM	PM
	69	460	810	280	210	36000	5600
	70			230	430	40	17
Totem Lk	71	4	1	10	58	58	35
	72	1700	1000	280	300	42	48
	73	5	4	22	47	5	6
	74	40	60	140	190	53	37
	75	100	360	34	130	17	18
	76	57	85	28	60	54	270
	77			160	160		
	79	110	93	300	460	290	59
	80	78	52	350	470	180	240
	81	69	54	400	360	71	100
	83	1	5	260	400	1100	1800

Billy Creek

Billy Creek drains the single family residences on the hill to the west of Kirkland, flows through a steep wooded ravine to the relatively flat residential area at the northwest corner of the City of Kirkland, entering the mainstem between sites 26 and 28. Unlike several of the other tributaries, Billy Creek had the highest counts in the upper portion of its basin (Table 9, Figure 5). Site 40 had low counts in July, but high counts during both the August and September rainy sampling events, with AM samples being twice as high as PM samples. Below the ravine the inverse was seen, with higher counts from site 43 downstream in July, and lower counts in this segment in August and September. Bacteria counts at the mouth of this tributary where it enters the mainstem were only moderately high in July when the flow from this creek was low and less than the counts in the mainstem during August and September. Site 40 should be investigated in Phase II.

Table 9. Fecal coliform bacteria counts (cfu/100ml) for sites in Billy Creek.

	July 30		August 27		September 24	
Billy Creek sites	AM	PM	AM	PM	AM	PM
40	5	10	1700	710	1800	800
42	100	60	61	60	25	26
43	680	59	120	150	190	52
44	700	530	110	120	600	51
45	570	420	190	160	90	78

Tributary A

Tributary A is a short small creek that starts at NE 121st ST, flows through a mobile home park and discharges into the mainstem just to the north of Juanita Beach Park between sites 33 and 34. There were higher counts at the upstream site (38) upstream of the mobile home park than near the mouth (39) in July when there was very little flow in the creek, but this pattern was reversed in August and September (Table 10, Figure 5). During the rainy sampling events there were predominantly high bacteria counts at the mouth. In September, the increase in this short section was nearly twenty fold.

Table 10. Fecal coliform bacteria counts (cfu/100ml) for sites in Trib A.

	July 30		August 27		September 24	
Trib A sites	AM	PM	AM	PM	AM	PM
38	230	110	110	450	26	21
39	82	67	330	270	470	410

Tributary S

Tributary S (85) is a small and the southernmost stream in the study area. This small stream is not part of the Juanita Creek drainage, but does discharge around 800 feet to the east of the swimming beach. Site 86 can more accurately be defined as a drainage ditch and discharges into Lake Washington in the same area as Tributary S. Site 86 had extremely high bacteria counts in July, but very little flow. This ditch drains the commercial area around NE Juanita Dr and NE 98th St. There have been very high count samples collected in this drain previously during sewage spill investigations and beach closures and the drainage area upstream of this drain outfall should be investigated in Phase II to ensure that the corrections that have already been implemented have been successful and corrected all sources in this area (Gaus, pers. Comm.).

Table 11. Fecal coliform bacteria counts (cfu/100ml) for sites in Tributary S.

		July 30		August 27		September 24	
sites		AM	PM	AM	PM	AM	PM
Trib S	85	450	120	200	280	280	120
stormdrain	86	1800	28000	580	670	160	220

Juanita Swimming Beach

In July and August, the bacteria counts at the beach were the highest on the east side of the swimming area (87) and decrease in the middle (88) to the west side (89) of the beach. This pattern is possibly contrary to what would be expected if Juanita Creek were consistently the primary source of the elevated bacteria counts during these sampling events. In July, flow out of Juanita Creek was low and the bacteria count in the stormdrain (86) immediately to the east of the beach was extremely high (AM 1800 and PM 28,000 cfu/100ml). This stormdrain had very low flow in July, but even in July (and during previous investigations at this location) the water in the ditch where the bacteria samples were collected was only separated from Lake Washington only by a wave-formed permeable sand berm no more than 3-4 inches high, and any flow associated with a spill could temporarily breach or flow through this insignificant barrier. Bacteria counts spiked at 28,000 cfu/100ml in the PM sample, over 15 times higher than the AM sample. This very large difference between the AM and PM samples does not indicate non-point source pollution or waterfowl but rather shows a high probability of being a point source. Because of the proximity of this drain to the swimming beach, the history of previous spill events (Jon Morrow pers. Comm.) and high bacteria counts in this ditch, this drainage ditch has an apparent direct influence the adjacent eastern section of the swimming area, this should be the first focus of Phase II.

On August 27 the count in the eastern section of the swimming area (87) of Juanita Beach Park was high enough to close the beach based on the King County swimming beach protocols. Typically, bacteria samples for beach monitoring are collected in the center section (88). However, due to the presence of potential bacteria sources on either side of the swimming beach and the high possibility that they may be of sanitary origin, it is recommended that Juanita Beach should be sampled at all three locations (87, 88, and 89) across the swimming area. This modification of the beach monitoring not only would provide more adequate human health risk information, but it may also allow for a portion of the swimming area to be closed without closing the entire swimming area. This protocol has been followed at Gene Coulon Park where the swimming are adjacent to John's Creek was closed to swimming without a full closure of the beach.

Comparing bacteria counts from the potential sources; site 37 mouth of the mainstem, site 85 Tributary S, and site 86 drainage ditch, the July data supports the hypothesis that inflow is a major driver of the bacterial pollution at the swimming beach. A comparison of the counts from the mainstem and Tributary S in August with the swimming area bacteria counts also point to these inflows as a possible source of the bacteria in the swimming area. In September, any inflow from the adjacent creeks would potentially dilute the bacteria counts in the swimming area. Low dry weather flows with high bacteria and early rain events with the widespread non-point wash off also seem to contribute to the high bacteria counts in the stream. Subsequent rain events, such as the September 24th storm may actually dilute the bacteria in the swimming area. This would support the low bacteria counts collected in the winter and prior to the start of the swimming season (http://green.kingcounty.gov/swimbeach/).

Table 12. Fecal coliform bacteria counts (cfu/100ml) for Juanita Swimming Beach and the discharge sites closest to the beach.

		July 30		August 27		September 24	
swimming beach	sites	AM	PM	AM	PM	AM	PM
	87	510	160	1100	560	170	970
	88	86	93	510	560	440	1200
	89	59	92	520	540	860	860
mouth	37	430	130	860	670	250	230
Ditch	85	450	120	200	280	280	120
TribS	86	1800	28000	580	670	160	220

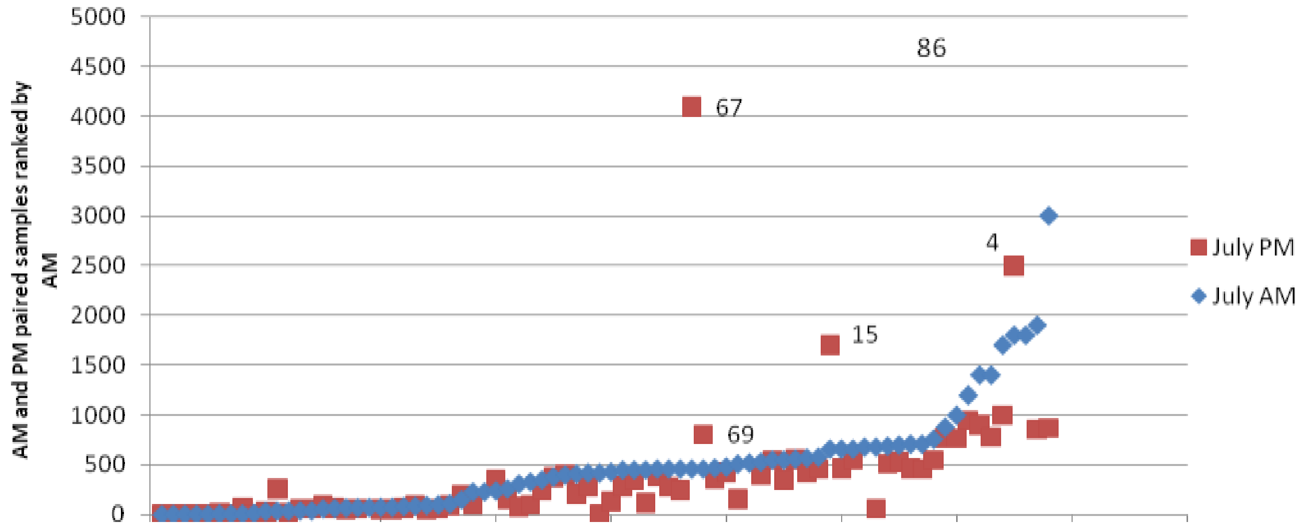
The patterns of water currents in this section of Lake Washington are not well known, and only by inferring from the direction of the creek mouth and sand accumulation is it hypothesized that the prevailing water currents is west to east (from the creek toward the swimming area). Specific data on the direction of creek flow into Lake Washington should be collected. If Juanita Creek water flows directly into the swimming area as suspected, temporarily redirecting the flows away from the swimming area would decrease the frequency of beach closures while the Phase II source identification and correction addresses the bacteria sources in Juanita Creek.

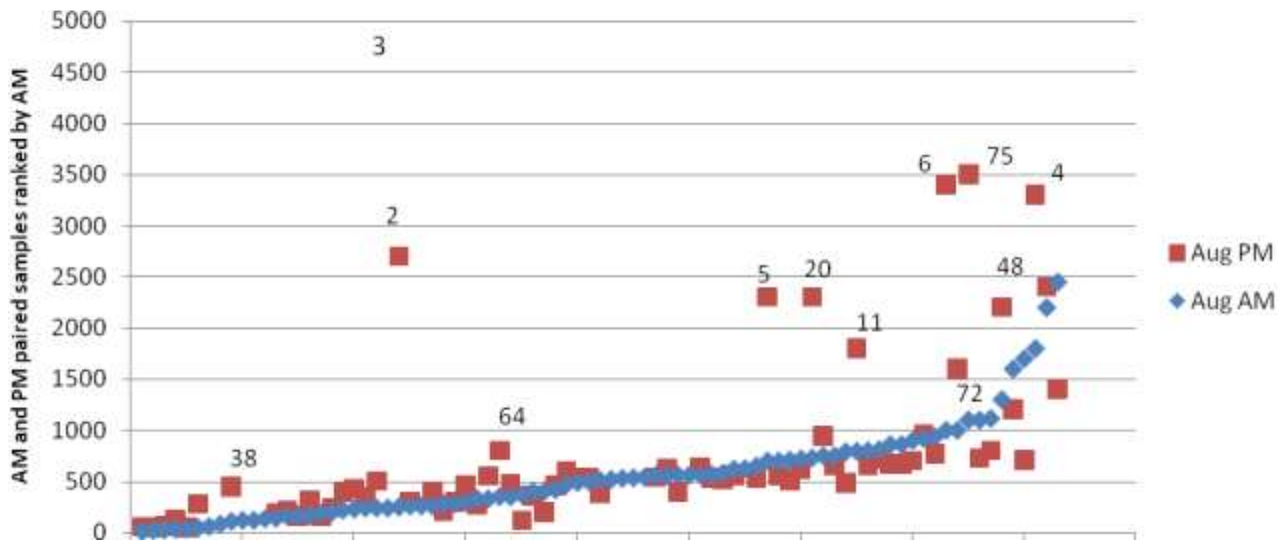
Comparing AM and PM sampling

To differentiate potential sanitary inputs from general background non-point sources of bacteria, one of the analyses used is comparison of the differences between morning (AM) (Figure 10; Table 13) and afternoon (PM) (Figure 11; Table 13) bacteria samples. Paired data of AM and PM bacteria counts at each site were ordered first by AM and second by PM for all three sampling events.

The assumption this analysis follows was that if the bacteria are from a non-point source, the counts would be relatively low (~≤ geometric mean) and there would be little difference between the AM and PM bacteria counts. This approach will only single out episodic sources that have large differences in bacteria counts over an approximately four hour period, the difference between the AM and PM sampling runs. A large difference between AM and PM counts would result from diel differences in water usage and sanitary flows, and would indicate an episodic bacteria source that may indicate a point source. Large differences between AM and PM bacteria counts ordered by AM bacteria counts would identify sites where potential PM point sources may be contributing bacteria; conversely data ordered by PM bacteria counts would identify sites where AM bacteria inputs are greatest. If Both the AM and PM bacteria counts are high, the high bacteria counts would indicate a chronic problem such as leaking pipes of cross connections. Non-point sources should not have large differences over the four hour sampling period.

Identifying morning bacteria 'spikes' was based on the paired bacteria counts ordered by AM bacteria counts (Figure -11) and using 800 cfu/100ml as an arbitrary, but relatively large bacteria count(> two times every geometric mean except for the August PM sampling geometric mean of (488 x 2 = 976). In July there were morning bacteria counts >1000 cfu/100ml at site 48 in the North Fork and at site 6, on the mainstem immediately upstream of the confluence the Kingsgate Tributary. Site 48 was apparently an example of observing the high bacteria counts downstream of the actual location based on the





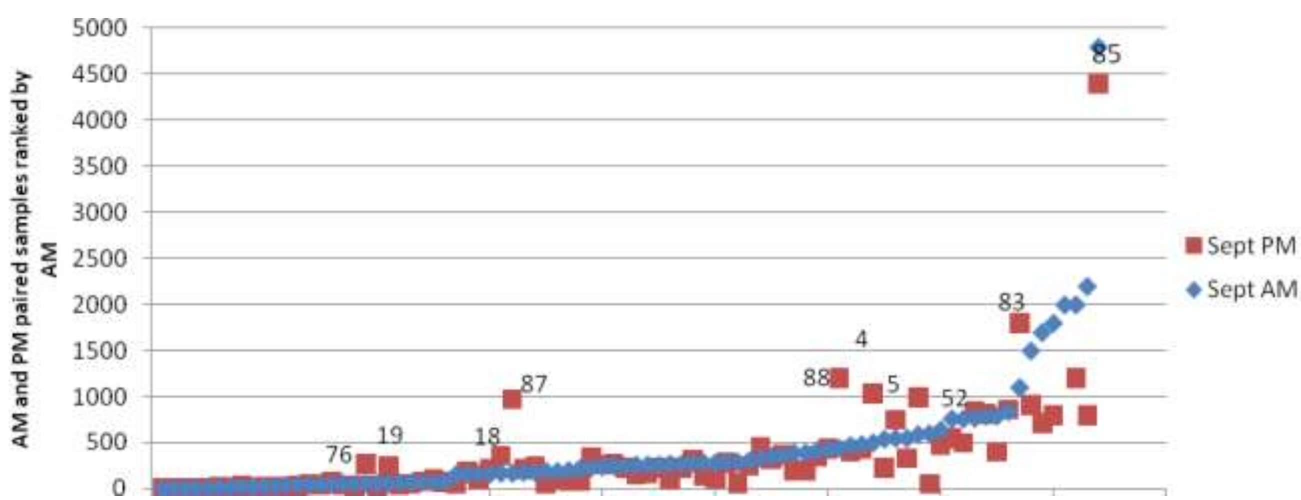


Figure 10. Fecal coliform bacteria counts (cfu/100 ml) for all samples ranked by AM samples to emphasize sampling sites with much higher PM bacteria counts, indicating afternoon episodic events.

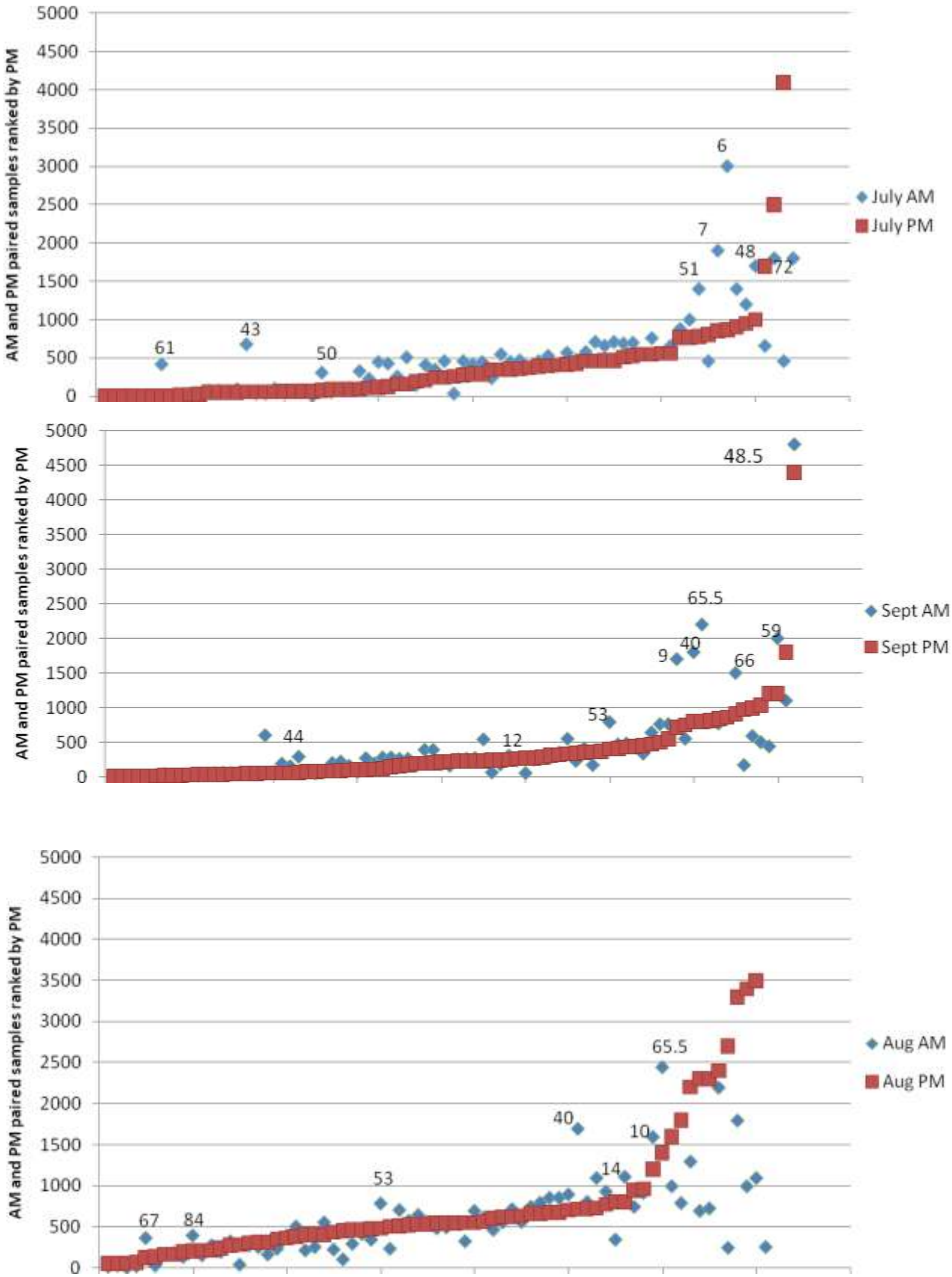


Figure 11. Fecal coliform bacteria counts (cfu/100 ml) for all samples ranked by PM samples to emphasize sampling sites with much higher AM bacteria counts, indicating morning episodic events.

establishment of site 47.5 upstream of site 48 and observing high counts at the new upstream sampling site in August and September. Site 6 is just above the confluence of the mainstem with the North Fork and just downstream of the confluence with the Kingsgate Tributary. The source of the high AM difference occurred between site 5 on 108th Ave NE at the downstream end of Edith Mouton Park and site 66, the lowest site on the Kingsgate Tributary, also on 108th Ave NE.

Afternoon spikes in July occurred at site 15 is on the mainstem of Juanita Creek, site 67 the pond in the Totem Lake Apartment complex, and site 86, the drainage ditch on Lake Washington east of the swimming beach (Figure 10). Site 86 had high bacteria counts both AM (1800) and PM (28,000). The high bacteria counts and large difference between AM and PM may help to identify the source of this pollution by looking for inputs that occur around or after noon. The high count in the pond is, which was not overflowing during July is probably associated with the cyanobacteria that was blooming during this sampling. Cyanobacteria tend to form surface scums in the afternoon and this scum may have trapped bacteria in the surface layer where it was sampled. Bacteria counts at site 15 were influenced by the bacteria counts from upstream in August and September, but there is no obvious source to account for the high bacteria count of 1700 cfu/100ml collected July PM(Table 2). The lack of an obvious source and an increase of 1040 cfu between the AM and PM sampling should be investigated in Phase II.

On the morning of August 27 only sites 40 and 65.5 had AM samples >1000 higher than PM samples. Site 40 is the uppermost site in Billy Creek and the entire headwater basin is in single family residences and had low flows and very low bacteria counts in July (AM 5, PM 10), but during the August and September sampling events the counts were August AM 1700 PM 710 and September AM 1800 and PM 800. The August and September AM samples were the highest bacteria counts in Billy Creek. Why there is an apparent AM slug of bacteria at this site should be investigated in Phase II.

Site 65.5 is the Retention Pond in the channel of the Kingsgate trib and was a site added upstream of site 66 because of the high July bacteria counts. The pond filled quickly during the rains and was overflowing by the time it was sampled in the mid morning, and was full and discharging on September 24 as well. This retention pond had the highest bacteria counts in the Kingsgate Tributary every time it was sampled. The immediate upstream sampling site (65) had an August 27 PM count of 500 cfu/100ml (AM was 240), but the September counts were AM 54 and PM 35. There is apparently a source of bacteria between site 65 and the outfall of the retention pond. The high counts collected at site 66, just downstream are lower (except for September AM where they are relatively equal) than at 65.5 and are probably a result of the bacteria discharging form this pond. This site needs to be investigated in Phase II. The high bacteria counts in this pond argue against designing pond in the middle of the channel.

During the August 27 sampling event eight sites had PM counts >1000 cfu/100ml higher than AM samples after a full day of rain. The highest increases were near the headwaters of the mainstem, with site 2 through 7 all having PM >1000 cfu/100ml AM. These increases in the upper portion of the mainstem at multiple sites downstream are indicative of non-point pollution wash off. Site 20 is a retention pond that had low bacteria counts in July. The Mickleson Ponds in the Kingsgate Tributary also had increases on August 27, but the increases were not high enough to get into the top ten PM increases. Another retention pond that was sampled was site 65.5 and this site had the largest difference between AM and PM. Apparently this pond (65.5) reacts quicker than the other retention ponds in the watershed. The only other retention pond that was sampled was site 57 in the upper portion of North Fork which had only a slight increase in August (AM 46 PM 280) and had very low bacteria counts in September (AM 19 PM 10). All of the sampled retention ponds in this watershed except for site 57 had large increases in bacteria counts after this first rain event. In-channel ponds seem to have a large impact on the increased bacteria measured in the first flush.

In August, the wide distribution of sites throughout the watershed with rainfall associated bacteria count increases indicates a non-point source to these bacteria count increases. A number of these sites were near the headwaters of the streams, and most of these sites had low bacteria counts during the July low flow dry weather sampling event. These increases in bacterial counts are probably responding to rain washing off accumulated bacteria and demonstrate a wide spread sources. The other major increase observed was at in-channel retention ponds in the middle or lower portions of the watershed.

In September, the rain had a greater impact on the AM samples than on the PM samples. The September distribution of high bacteria counts was not as geographically ‘organized’ as in August. The largest bacteria count was sampled in AM at site 69, at Totem Lake Commerce Center parking lot below the culvert. The AM sample of 36,000 cfu/100ml was the highest bacteria count recorded for the entire study. The large decrease to PM 5600 makes these counts look like a point source, and needs to be identified and corrected in Phase II. Additionally, the basin this ditch drains is highly developed and primarily impervious. It would be hard to develop scenarios that would support a non-point source to these counts. Both sites 65.5 and 40 had high AM bacteria counts relative to PM like what was seen in August.

September PM after a full morning of rain there were no sites that had >1000 cfu/100ml above the AM samples. Perhaps by the afternoon most of the wash off had already occurred. The largest PM increased was at the eastern sampling site (87) in the swimming area. The central sampling site at the beach (88) also had higher PM bacteria (1200), but this site also had high AM (440) counts.

A nuance of this experimental design is the fact that water runs downstream, and sampling very large bacteria counts at a particular site does not necessarily identify that site as the source, but rather a source of the bacteria is somewhere upstream. This is true for all the data collected to identify sources of bacteria. The construction of stream segments bracketed by the sample sites was designed to account for the downstream flow of water and the bacteria the streamflow carried. All sites and the area draining to the stream from upstream with exceptionally high bacteria counts (>1000 cfu/100ml) will be investigated in Phase II.

Table 13. Ten largest differences between AM and PM bacteria counts (cfu/100ml) for every sampling event

Ten largest differences AM minus PM indicates AM inputs											
July				August				September			
site	AM	PM	AM -PM	site	AM	PM	AM -PM	site	AM	PM	AM -PM
37	430	130	300	84	400	200	200	12	540	230	310
85	450	120	330	21	710	510	200	53	790	400	390
87	510	160	350	16	900	700	200	58	4800	4400	400
61	420	5	415	67	370	120	250	44	600	51	549
5	1400	905	495	53	790	480	310	66	1500	910	590
7	1400	780	620	15	1115	800	315	59	2000	1200	800
43	680	59	621	14	1100	725	375	51	1700	710	990
72	1700	1000	700	10	1600	1200	400	40	1800	800	1000
48	1900	860	1040	40	1700	710	990	65.5	2200	800	1400
6	3000	870	2130	65.5	2450	1400	1050	69	36000	5600	30400
Ten largest differences PM minus AM indicates greater PM inputs											
July				August				September			
site	AM	PM	PM -AM	site	AM	PM	PM -AM	site	AM	PM	PM -AM
89	59	92	33	9	1000	1600	600	16	335	450	115
3	150	200	50	48	1300	2200	900	19	63	240	177
68	9	70	61	11	795	1800	1005	18	170	360	190
18	240	350	110	4	1800	3300	1500	5	550	750	200
57	37	260	223	20	730	2300	1570	76	54	270	216
69	460	810	350	5	700	2300	1600	52	590	990	400
4	1800	2500	700	6	1000	3400	2400	4	500	1035	535
15	660	1700	1040	7	1100	3500	2400	83	1100	1800	700
67	460	4100	3640	2	250	2700	2450	88	440	1200	760
86	1800	28000	26200	3	260	6900	6640	87	170	970	800

Locating specific bacteria sources

In this study a total of 235 samples were collected at 88 sampling locations, only 33% of the samples met the WAC173-201A water quality criteria for extraordinary primary contact of 50 cfu/100ml fecal coliform. Several probable point sources have been identified in this study, and several other probable sources have been tentatively located to areas around short stream segments and the relatively small portion of the watershed that drains into the segments. All of these bacteria sources have obvious impacts on the bacteria counts at downstream locations that may or may not be contributing to the bacteria pollution in the creek. But the widespread exceedances of the bacteria standards in two-thirds of the samples in the study show there is a significant non-point contribution to the bacteria pollution in the Juanita Creek watershed.

Phase II of this study is designed to locate the exact sources of the high bacteria counts so those sources can be controlled and the bacteria in Juanita Creek reduced so both the creek and beach are removed from the 303(d) category 5 water quality list and the swimming beach remains open. Because bacteria counts are high across the watershed, any source that can be identified needs to be corrected and a non-point control program needs to be implemented as soon as possible. The likelihood of locating these bacterial sources is increased by identifying smaller areas to search for sources.

The sites that had high bacteria counts (Table 14), stream segments that had large increases between immediate upstream and downstream sampling sites (Figures 12-17), and the sub-basins that drain into those segments (Figure 18) will be investigated to locate and control those bacteria sources.

Table 14. Ten highest bacteria counts or counts >1000 (cfu/100ml) for every sampling event

Highest AM bacteria counts								
July			August			September		
site	AM	PM	site	AM	PM	site	AM	PM
6	3000	870	65.5	2450	1400	69	36000	5600
48	1900	860	12	2200	2400	58	4800	4400
86	1800	28000	4	1800	3300	65.5	2200	800
4	1800	2500	40	1700	710	59	2000	1200
72	1700	1000	10	1600	1200	40	1800	800
5	1400	905	48	1300	2200	51	1700	710
7	1400	780	15	1115	800	66	1500	910
66	1200	950	7	1100	3500	83	1100	1800
51	1000	770	14	1100	725	89	840	860
58	880	770	6	1000	3400	48	790	815
			9	1000	1600			
Highest PM bacteria counts								
July			August			September		
site	AM	PM	site	AM	PM	site	AM	PM
86	1800	28000	3	260	6900	69	36000	5600
67	460	4100	7	1100	3500	58	4800	4400
4	1800	2500	6	1000	3400	83	1100	1800
15	660	1700	4	1800	3300	59	2000	1200
72	1700	1000	2	250	2700	88	440	1200
66	1200	950	12	2200	2400	4	500	1035
5	1400	905	20	730	2300	52	590	990
6	3000	870	5	700	2300	87	170	970
48	1900	860	48	1300	2200	66	1500	910
69	460	810	11	795	1800	89	840	860

Information that has been developed in this study will be used to conduct the search for sources in Phase II. Suspect sources have been identified to general small drainage areas by analyzing the distribution and timing of the bacteria counts from all of the sampling events. The primary data that will be of use in Phase II is the GIS layers identifying the stream segments that are of greatest concern (large increases between adjacent upstream and downstream sampling sites), and the small sub-basins that have been delineated as draining into these stream segments.

These sub-basins were delineated by a combination of datasets, primarily the lidar coverage of topography from the King County GIS database (Figure 18). These small topographic basins were modified by overlaying the storm drain coverage (City of Kirkland) and the local sanitary sewer line coverage (King County). These basin delineation modifications follow the assumption that the original source of the bacteria is unknown and may enter the surface water where it was sampled via either leaks in the sanitary system or the stormdrain network, which often do not follow exactly the surface topography. Non-point sources of bacteria potentially enter the surface water or storm drains following topographic flow paths. The sub-basin GIS layer has been provided to the City of Kirkland electronically.

Top Priority Sites to be Investigated for Source Control

Totem Lake Commercial Area - Sites 69, 72 and 83

These sites had bacteria counts on at least one of the three sampling dates so far above the bacteria counts collected during the other sampling events that there is a very high probability that these samples were collected during sanitary overflow events. These were episodic pollution events l in a heavily developed, paved, and piped upper portion of the Totem Creek watershed where there is little possibility that non-point sources could contribute to these high counts. This study does not provide information on how frequently these sites may have these very high bacteria events, as they were only sampled on three days over a three month period. The lack of open channels draining to these sites makes sanitary overflow the probable source of this pollution, and increases the potential health risks of the high bacteria. The City of Kirkland has detected and corrected sanitary problems in this area in 2008.

 # 69 -- Action Items:

1. Kirkland will conduct follow up sampling to determine whether this was a lab anomaly. If testing shows a continued problem, Kirkland will do some further investigating to determine the likelihood of sanitary overflows in this area. There is a shallow sewer line that runs under the ditch. The stormwater system in the business park has been cleaned and repaired, but may need to talk with business park owner about BMPs.
2. Public Health may be asked to assist through dye testing in Phase II.

 # 72 - Action Items:

1. Kirkland will talk with NUD to get a complete history of overflows in this area.
2. NUD will set up regular cleaning/flushing schedule with restaurant for grease removal as part of Phase II. Kirkland will coordinate with NUD to set this up.
3. Kirkland will monitor monthly at site #72 to determine the effectiveness of monthly cleaning. Bacteria levels may continue to be high due to presence of a reservoir of bacteria in the pond, but should not get higher.

#83 - Action Items:

1. Ecology will begin sampling monthly upstream and downstream (site #83) of the wetland at the following sites:
    - TOT83A – downstream at CMP culvert
    - TOT83B – downstream at flow under driveway (sample @ west side)
    - TOT83C – upstream @ 113th & 120th above wetland
2. Data from this monthly sampling will be reviewed after one year of data collection as part of Phase II.

TRIBUTARY S - Site 86

This site is a small drainage ditch that discharges into Lake Washington in the same area as Tributary S (site 86) around 800 feet to the east of the swimming beach and appears to have an impact on the bacteria counts in the swimming area. Site 86 had extremely high bacteria counts in July, but very little flow. This ditch drains the commercial area around NE Juanita Dr and NE 98th St. There have been very high count samples collected in this drain previously during sewage spill investigations and beach closures. Dye testing was done in the summer of 2008 in shopping mall bathrooms on the north side of 9714-9718 Juanita Drive. No cross-connections between sanitary and storm were found, but there is a storm water pipe in the parking lot that has a reverse grade and so retains water. It is also possible that the espresso stand located in the parking lot adds to the bacterial load. There are no plans at this time to straighten out the pipe.

#86 Action Items:

1. Kirkland will set up a monthly cleaning schedule for this pipe during the swimming season as part of Phase II.
2. Kirkland will investigate the sewer connection and waste disposal practices of the espresso stand.
3. Kirkland will monitor monthly at site #86 to determine the effectiveness of monthly cleaning.

NORTH FORK JUANITA – Site 58

The highest counts in the North Fork were sampled in and were the second highest sample pair collected during September. No obvious source was observed and this area which drains single family residences. There may have been ditch maintenance at the Park and Ride lot on Juanita-Woodinville Way NE across from NE 115th Ave. The stream segments between sites 57 downstream to site 3.5 on the mainstem need to be investigated for sources. Bacteria entering Juanita Creek along this stretch of stream causes high bacteria counts further downstream masking any other potential sources in the middle segments of the mainstem. This area needs further investigation to determine flow path with detailed mapping. Stream runs in a channelized ditch in an area that drains single-family residences.

#58 Action Items:

1. Kirkland has NUD's most recent septic/sewer layers and will provide to King County.
2. County will get the most recent septic list from NUD.
3. Ecology will monitor station #58 (JUAN112) monthly for one year. Collecting QPCR filters may be included in 2010 if funding for analysis is secured.
4. After reviewing NUD's information, Public Health may be asked to assist potential dye testing.

KINGSGATE TRIBUTARY – Sites 65, 65.5, and 66

This Kingsgate Tributary segment had one of the highest increases between sites (65 and 65.5). The in-channel retention pond immediately upstream of 65.5, needs to be tested as a potential bacteria generating site. There was a waterline replacement project in August 2008 in this area and the construction workers indicated that there would also be sewer line work in the area. The bacteria count increase along this stream segment was even greater during the September sampling. NUD installed a sewer line across from Juanita High School but at the time of this survey only a few homes had connected. The King County 'sewerland' .GIS layer shows some parcels in the area that are not hooked up to the sewer system.

Note: Site #66 is monitored as part of the Juanita Retrofit project. During a storm event in August, this site had high TP, TN, BOD, TSS, fecal coliform bacteria and copper (unpublished data).

 # 65, 65.5, and 66 Action Items:

1. Kirkland has the most recent septic/sewer layers from NUD and will provide to King County.
2. County will get the most recent septic list from NUD.
3. Ecology will sample monthly at the following stations:
    - #66 (EJUAN)
    - below the pond @ three discharges below road (#65.5: EJN65.5A, E-JN65.5B, EJN65.5C)
    - above the pond in creek (EJN65.5X) behind residence @ 13413 110th place NE
    - and further upstream in creek at #65 (EJN132)
    - collecting QPCR filters may be included in 2010 if funding for analysis is secured.
4. After reviewing NUD's information, Public Health will be asked to assist potential dye testing.

MAINSTEM – Site 15

This site in on the Juanita mainstem segment (between sites 65 and 65.5) and was apparently influenced by the bacteria counts from upstream in August and September, but there is no obvious source to account for the high bacteria count of 1700 cfu/100ml collected July PM(Table 2). The lack of an obvious source and the large increase of 1040 cfu/100 ml between the AM and PM sampling should be investigated in Phase II. Control of upstream sources will make identification of potential sources in the middle and lower sections of Juanita Creek easier.

NOTE: Hidden View Condo area is currently under enforcement because blackberry was removed from the banks and wood was removed from the stream. There is a sewer line that was patched by the property owners and may have not been patched effectively.

#15 Action Items:

1. Ecology will monitor #15 monthly (JUAN15). Collecting QPCR filters may be included in 2010 if funding for analysis is secured.
2. Kirkland is investigating the portion of the sewer line that was repaired.

BILLY CREEK – Site 40

This site is the uppermost site in Billy Creek where the entire headwater basin is in single family residences with low stream flows and very low bacteria counts in July (AM 5, PM 10), but during the August and September sampling events the counts were August AM 1700 PM 710 and September AM 1800 and PM 800. The August and September AM samples were the highest bacteria counts in Billy Creek and much higher than the PM samples indicating a possible episodic event. This site drains a residential area with septic systems. The high A.M. fecal counts after ground is saturated may indicate septic systems are not functioning properly. Kirkland staff noted large quantities of dog waste in this area that may be contributing as well.

#40 Action Items:

1. Ecology will monitor this site #40 monthly (BILL40A) and east of this site above NE 134th Street (BILL40B). Collecting QPCR filters may be included in 2010 if funding for analysis is secured.
2. King County will review septic records in this area and work with Public Health to assist with potential dye testing.

UPPER WEST FORK - #47.5 and 48

Samples collected upstream of the pump station reconstruction at 47.5 indicate that fecal source occurs upstream of pump station. Samples collected at 48 had brown foam.

#47.5 and 48 Action Items:

1. Ecology will add station 47.5 (WFJN47.5 @ NE 145th St & 88th Avenue NE blow road) and 48 (WFJN48) to their monthly monitoring. Collecting QPCR filters may be included in 2010 if funding for analysis is secured.
2. King County will review septic records in the area of 47.5 and work with Public Health to assist with potential dye testing.

UPPER WEST FORK - #51

Water quality samples collected as part of the Retrofit Project at a station between 51 and 52.during a storm in August 2009 exhibited high ammonia, ortho-P, BOD, and fecals indicating a potential sewage source (unpublished data).

#51 Action Item:

1. Ecology add station 51 (WFJN51) to their monthly monitoring. Collecting QPCR filters may be included in 2010 if funding for analysis is secured.
2. King County will review septic records in the area of 51 and work with Public Health to assist with potential dye testing.

Juanita Swimming Beach – Sites 87, 88, and 89

If Juanita Creek water flows directly into the swimming area and contributes to the excessive bacteria counts in the swimming area as suspected, temporarily redirecting the flows away from the swimming area by modifying the outlet of the stream could decrease the frequency of beach closures while the Phase II source identification and correction addresses the bacteria sources in Juanita Creek. Kirkland conducted a goose removal in early summer of 2009. Bacteria counts in the swimming area dropped, and then remained low all summer following this action. Geese are also considered as a major source of contamination.

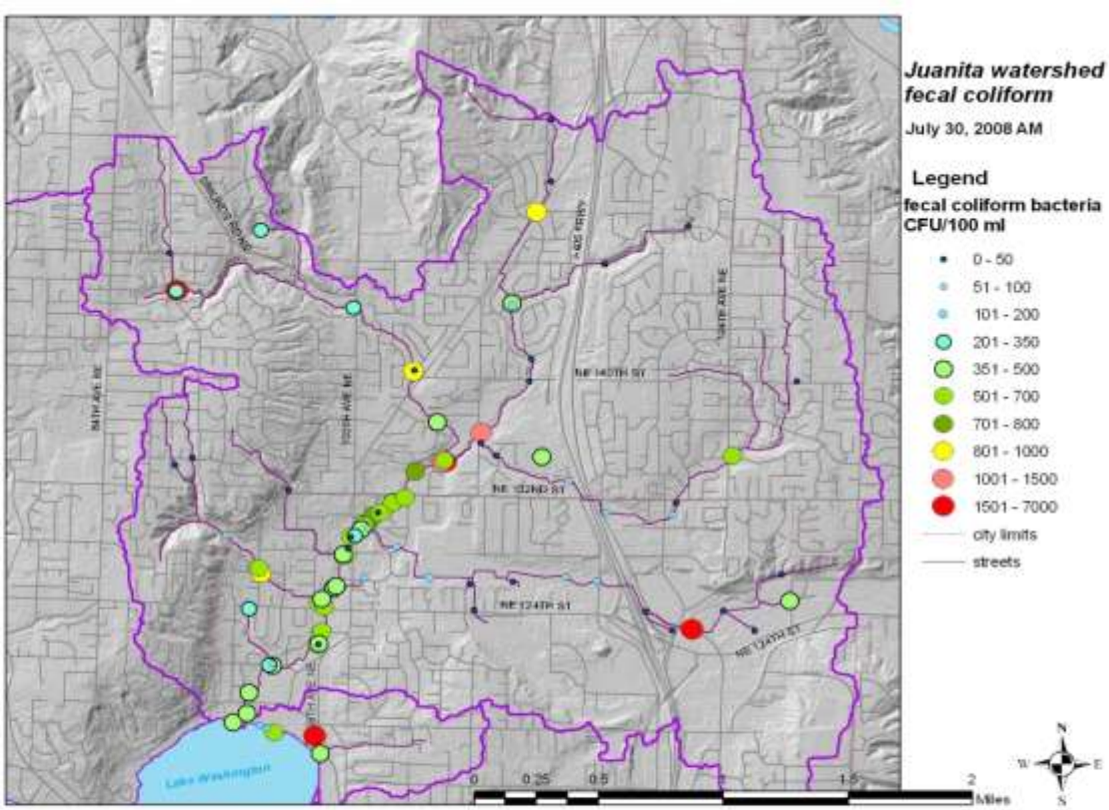
Conclusion

Other watersheds that have bacteria problems have investigated non-point sources by ribotyping bacteria collected in the surface waters. This watershed is heavily developed and very little waterfowl was observed beyond Juanita Beach Park. Waterfowl have been identified as sources of bacteria at the swimming beach (King County, unpublished data). Other studies have identified pets, livestock and wildlife (includes rodents) as major contributors. There is little, if any livestock in this watershed. King County and the City of Kirkland could implement a pet waste control program similar to the one in Snohomish County to address these sources of bacteria.

The counts of fecal coliform bacteria in the Juanita Creek watershed are high enough to suggest a potential public health risk from an increased risk of pathogen induced illness to human (EPA 2001). Ecology is guided by Washington's Water Quality Management Plan to Control Nonpoint Source Pollution (Ecology 2000). Bacteria contributed by wildlife are considered as natural background and not a target for reduction by TMDLs. Waterfowl have been identified at Juanita Beach Park as a major source of bacteria using ribotyping (King County unpublished data). However, no excessive concentrations of waterfowl or wildlife have been reported in the sections of the Juanita watershed where high inputs of fecal coliform bacteria have been collected during this study.

Kitsap County Health District posts streams as contaminated when the geometric mean value of fecal coliform bacteria is >270 FC/100ml, the most likely months when people would be in contact with the streams. This standard is based on an epidemiological study of swimming beaches in Europe. Young and Thackston (1999) reported a direct link between the density of development, population, impervious surfaces and fecal bacteria density. Several high fecal coliform bacteria events that resulted in the closure of the public swimming beach were traced to sewer overflows from pipes clogged with grease, broken sewer lines, (Jon Morrow, pers com).

This study attempted to identify as many of the unidentified, un-located point sources as possible and correct and eliminate these pollution sources in Phase II.



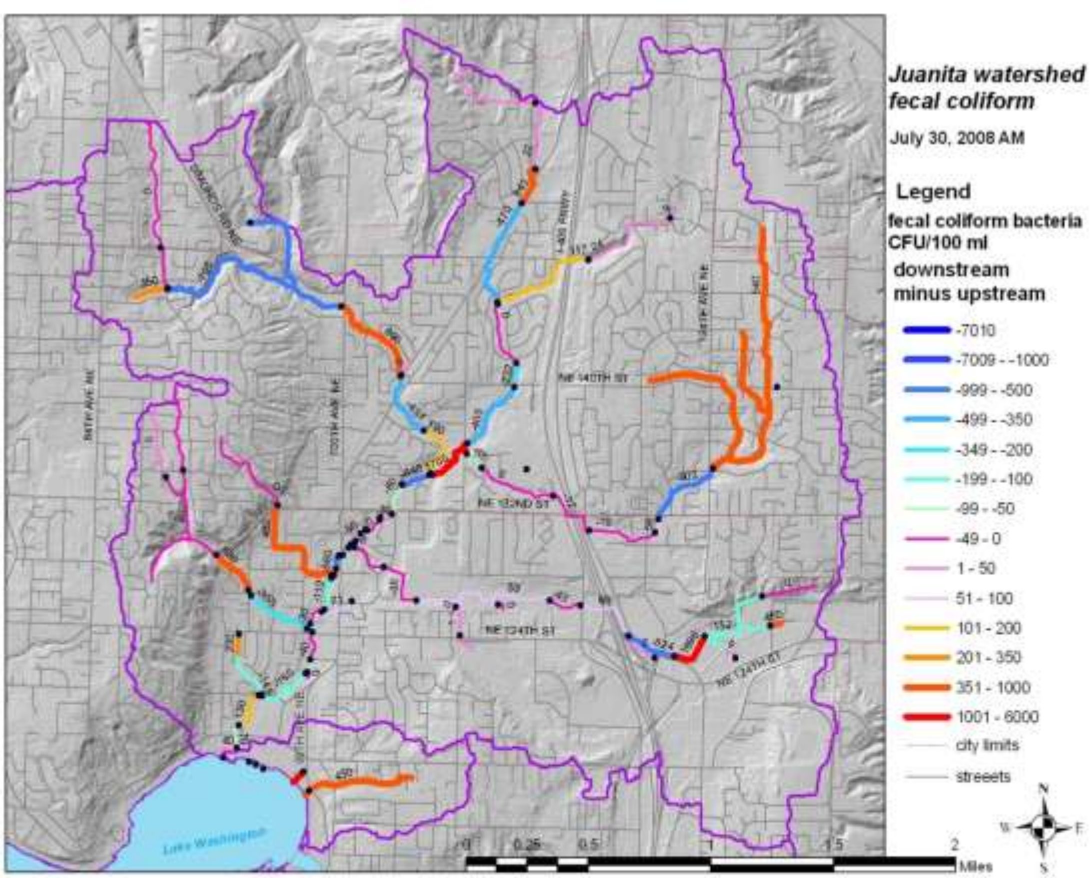
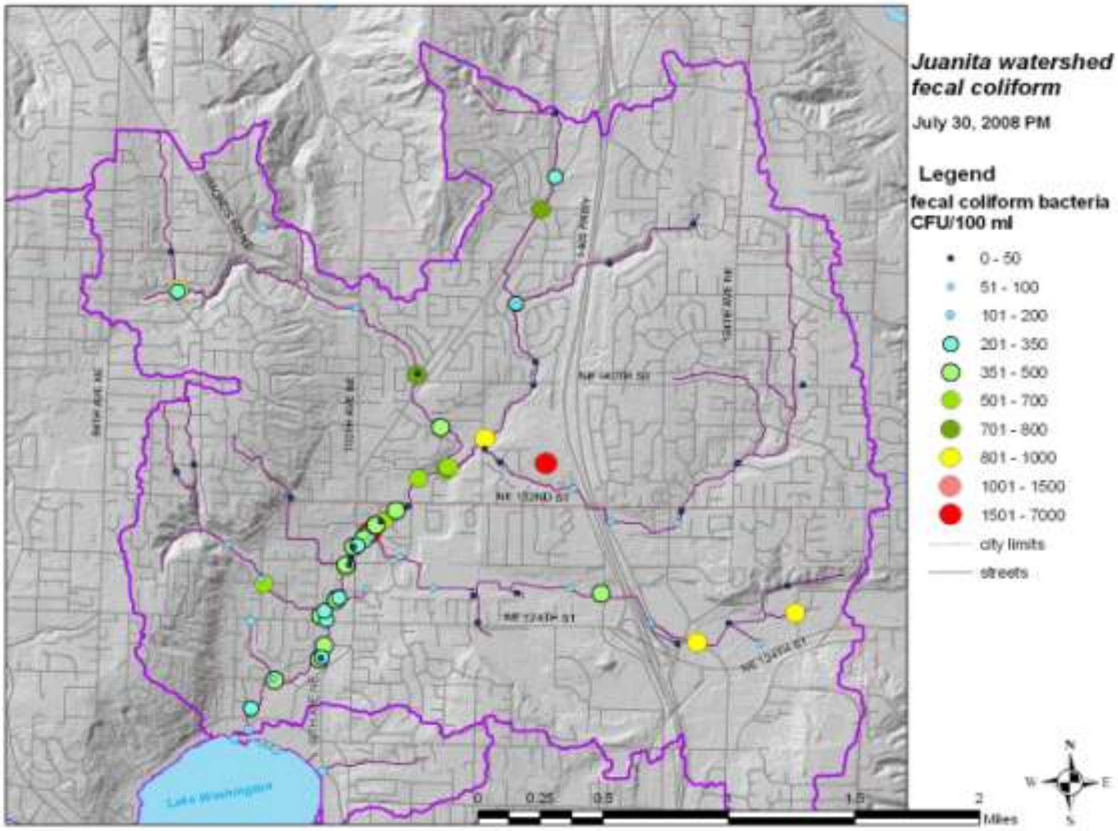


Figure 12: Fecal coliform bacteria counts and stream segments (downstream minus upstream bacteria counts) in the Juanita Creek watershed for July 30, 2008 morning samples.



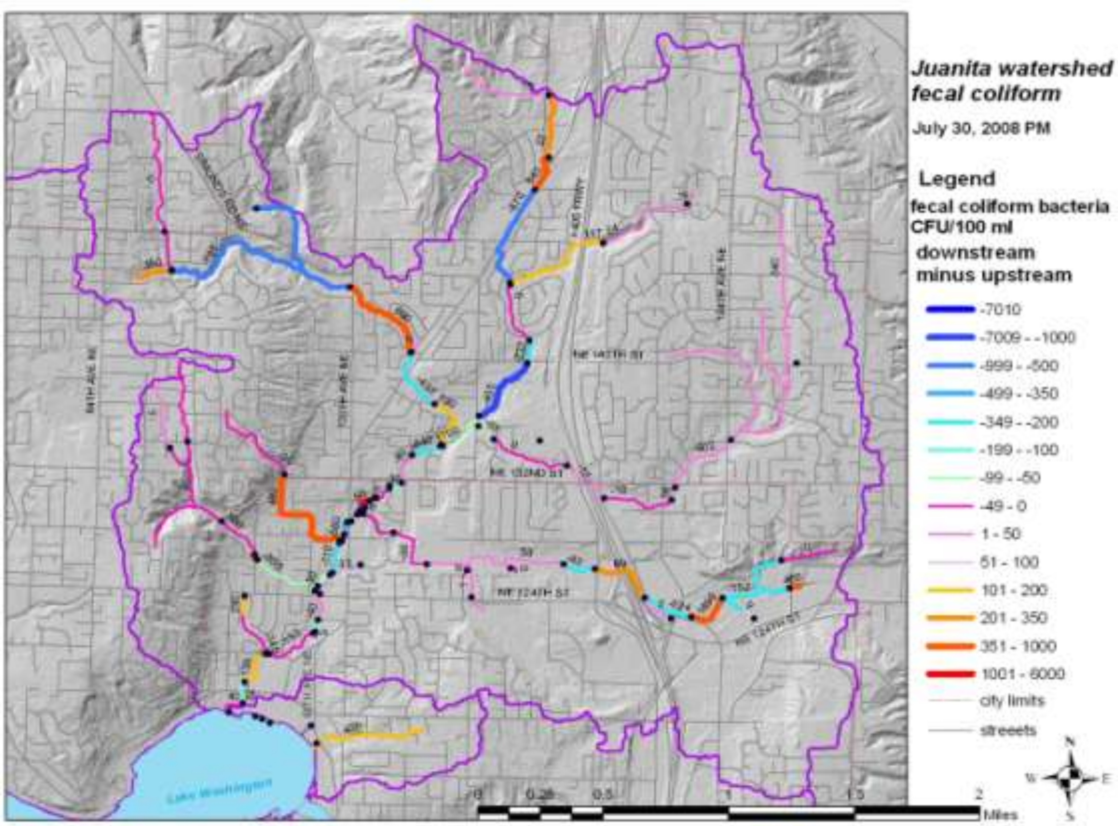
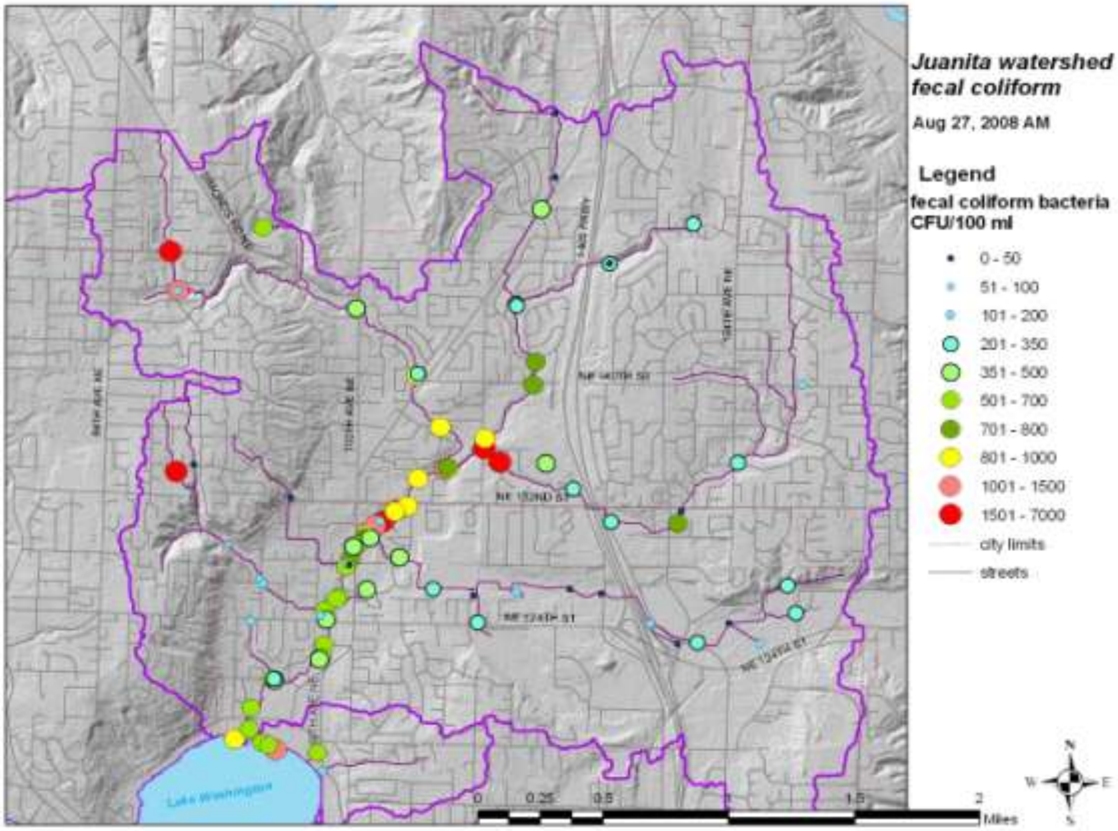


Figure 13: Fecal coliform bacteria counts and stream segments (downstream minus upstream bacteria counts) in the Juanita Creek watershed for July 30, 2008 afternoon samples.



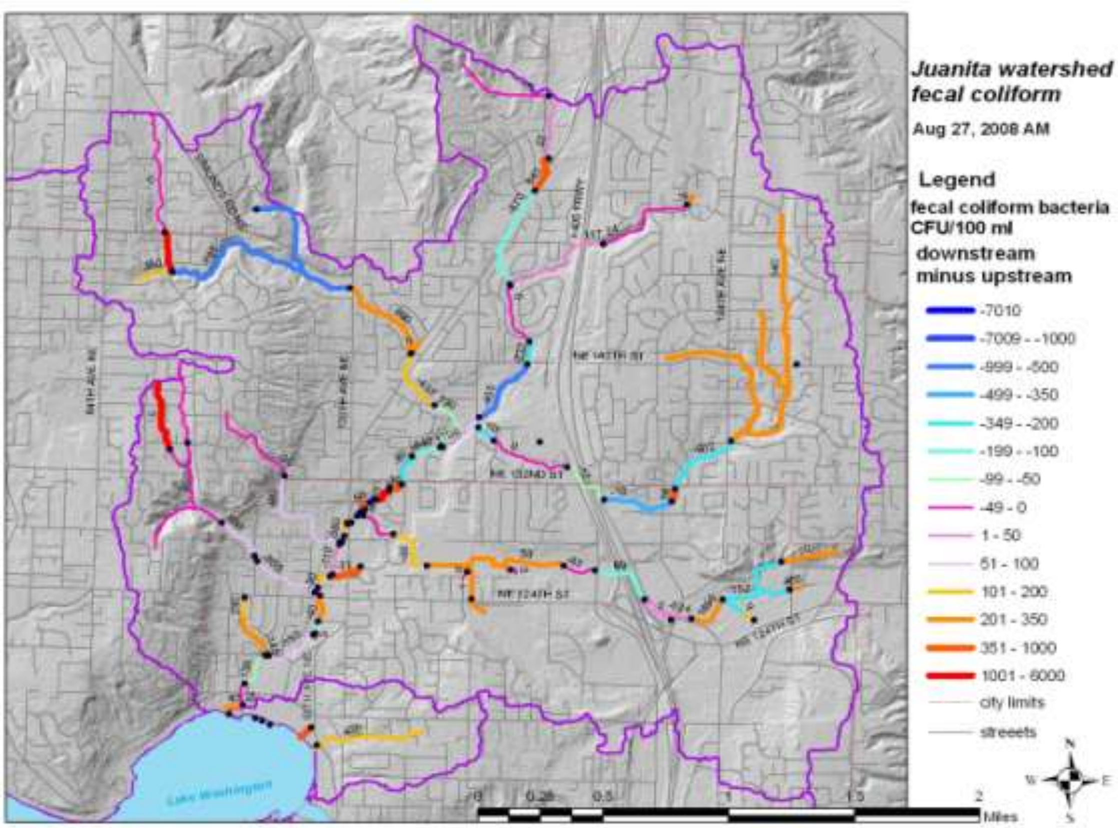
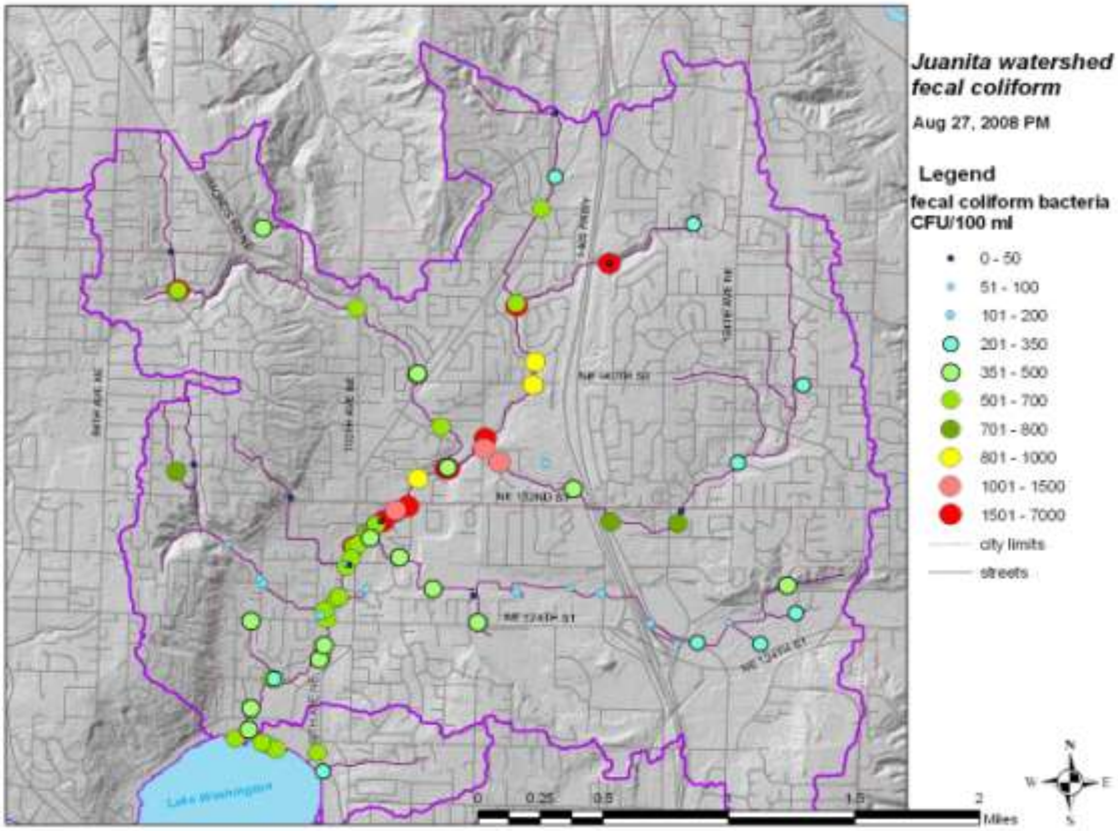


Figure 14: Fecal coliform bacteria counts and stream segments (downstream minus upstream bacteria counts) in the Juanita Creek watershed for August 27, 2008 morning samples.



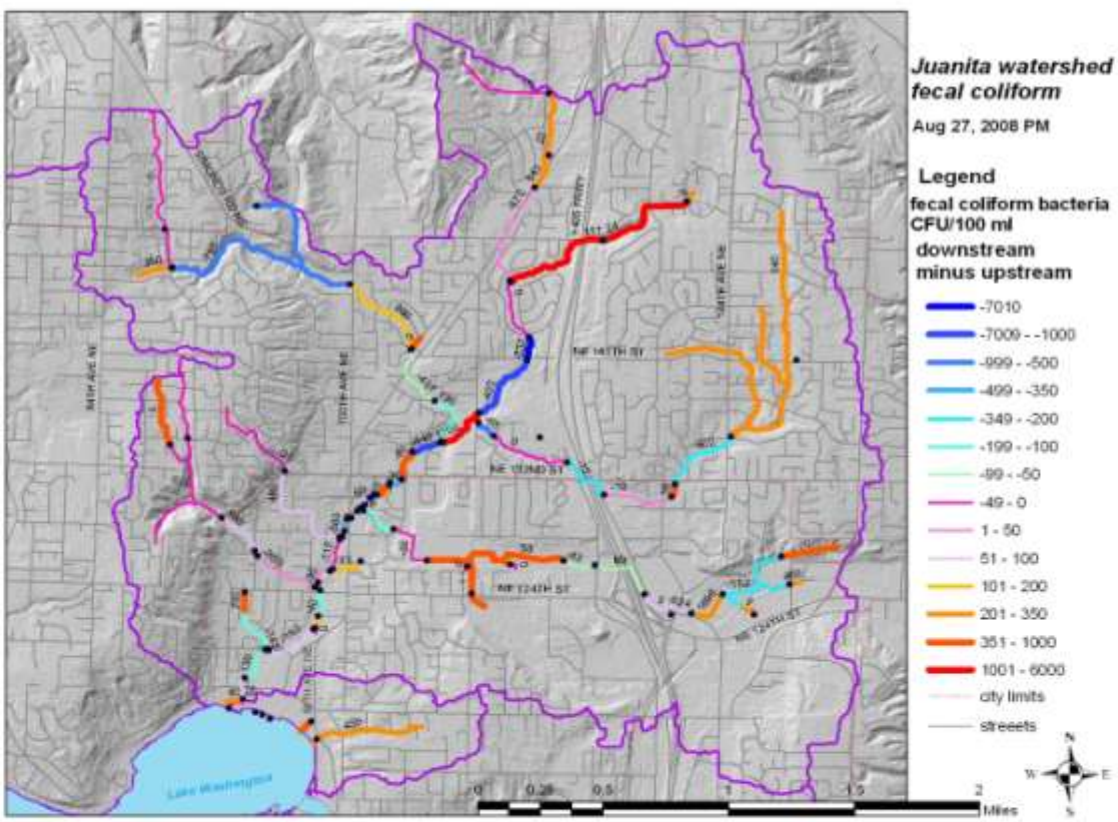
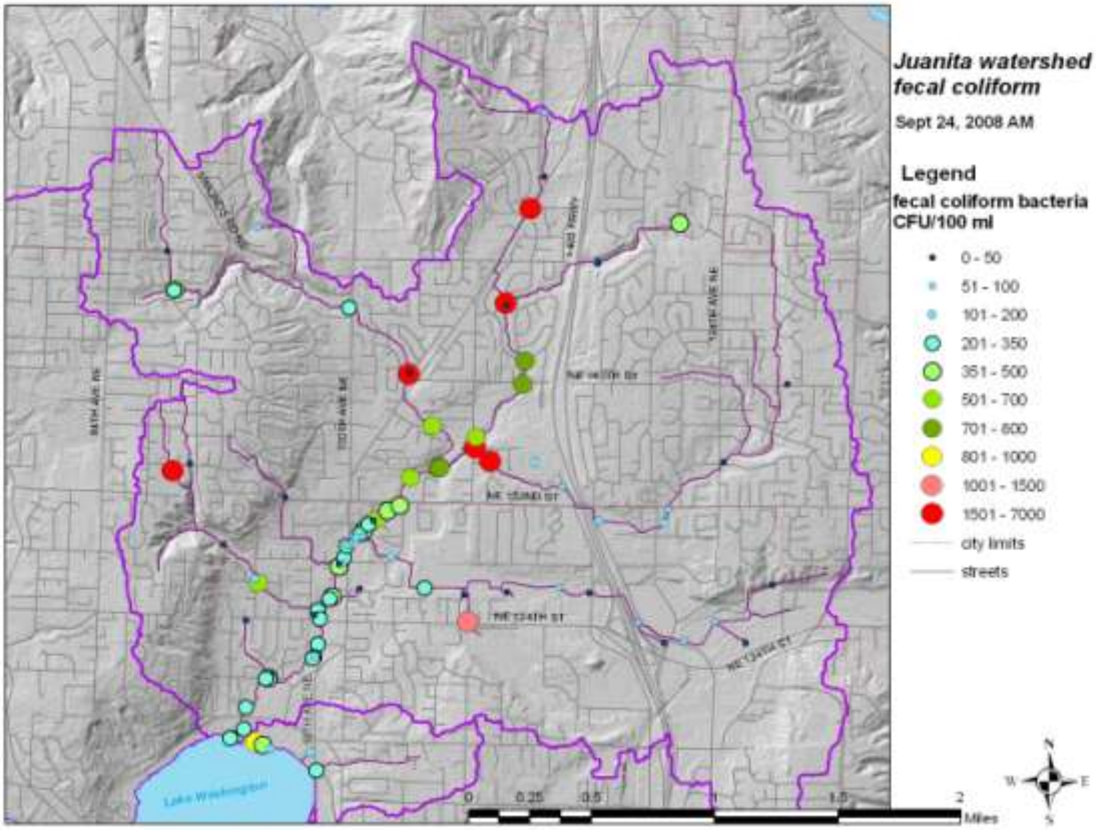


Figure 15: Fecal coliform bacteria counts and stream segments (downstream minus upstream bacteria counts) in the Juanita Creek watershed for August 27, 2008 afternoon samples.



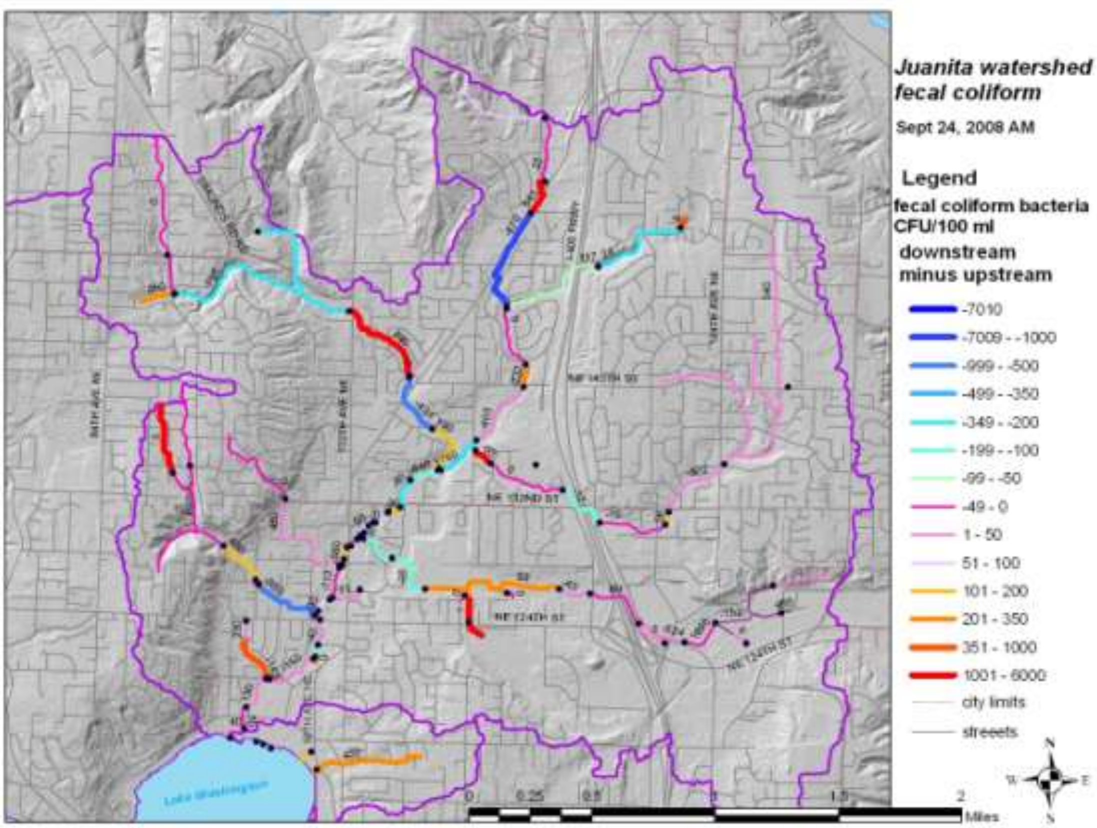


Figure 16: Fecal coliform bacteria counts and stream segments (downstream minus upstream bacteria counts) in the Juanita Creek watershed for September 24, 2008 morning samples.

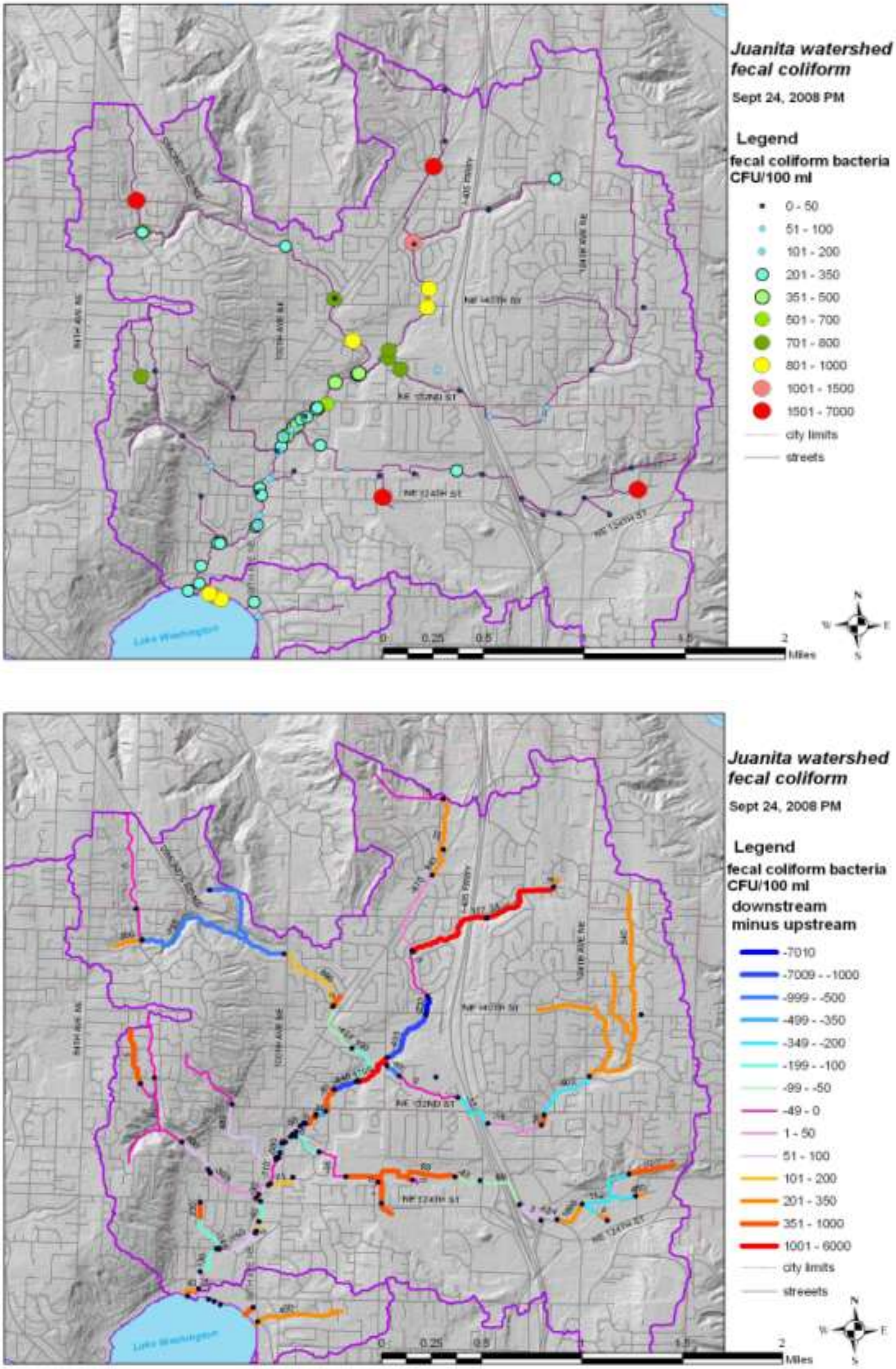


Figure 17: Fecal coliform bacteria counts and stream segments (downstream minus upstream bacteria counts) in the Juanita Creek watershed for September 24, 2008 morning samples.

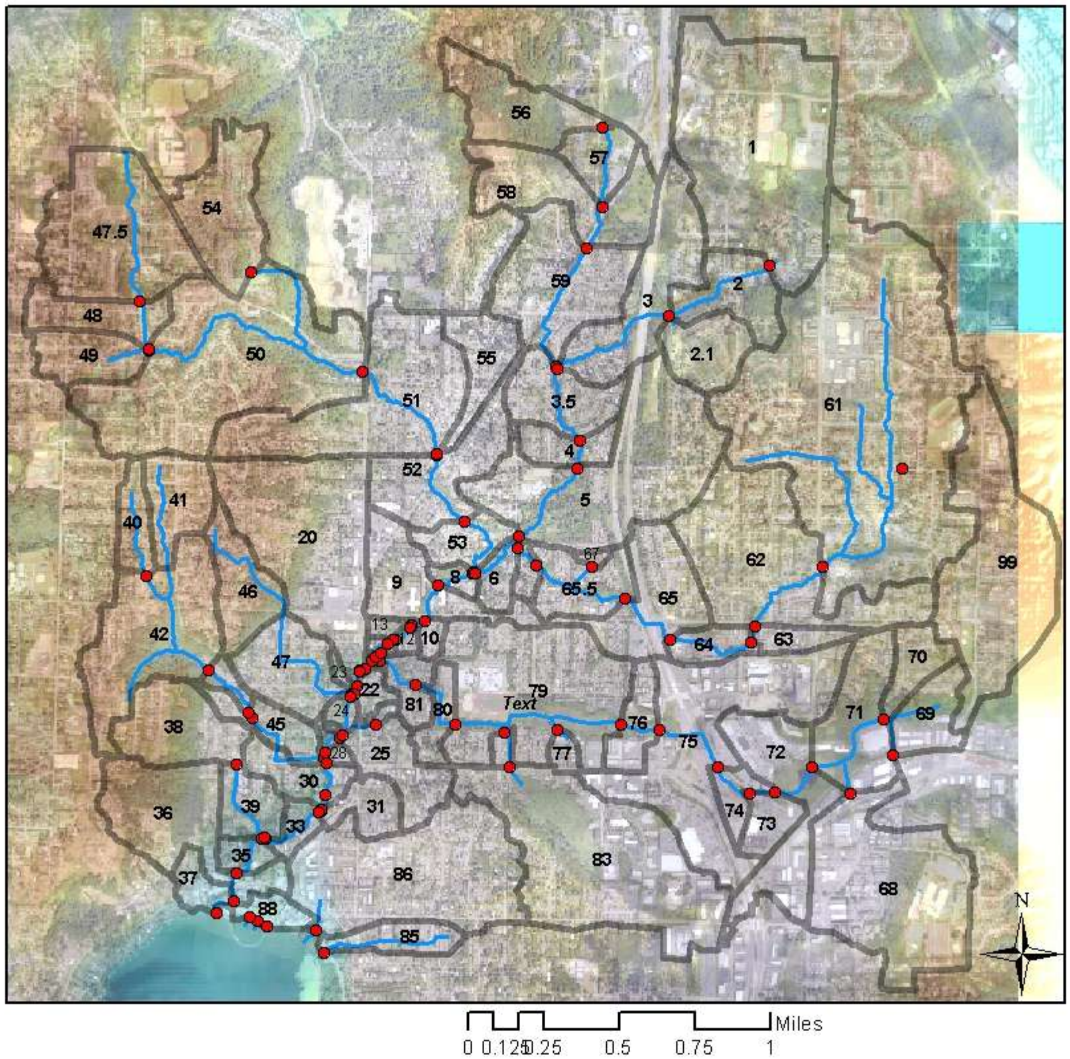


Figure 18. Sub-basins in the Juanita watershed deliniated by areas that drain into stream segments defined by sampling sites. Sub-basin boundries defined by topography from lidar, storm sewers (City of Kirkland GISdata), and sanitary sewers (King County GIS data). Basins are numbered the same as the downstream sampling site.

References

Ecology 2000. Washington's Water Quality Management Plan to Control Nonpoint Pollution. Washington Department of Ecology, Water Quality Program, Olympia, WA. Publication No. 9-26, 381 pp.EPA, 2001. Protocol for Developing Pathogen TMDLs, First Edition, EPA 841-R-00-002, Office of Water, U.S. Environmental Protection Agency, Washington D.C. January 2001.

King County 2005. *Standard Operating Procedure for Analysis of Fecal Coliforms in Environmental Waters by Membrane Filtration*, SOP #506. King County Environmental Laboratory. Seattle, Washington.

King County 2006. *Standard Operating Procedure for Field Measurements using an Attended Hydrolab*, SOP #205v4. King County Environmental Laboratory. Seattle, Washington.

King County 2006. *Quality Assurance Manual, Revision 2*. King County Environmental Laboratory. Seattle, Washington. Parametrix, 2005. *City of Kirkland Surface Water Master Plan*.

McLaughlin, J. 2008. *Baseline Survey of E. coli in Juanita Creek, Kirkland, Washington, July 2007-Feb 2008.*

Gaertner, J. 2009. *Correlating precipitation, discharge and water temperature to E.coli concentration in Juanita Creek*.

Young, K.D. and E.L. Thackson, 1999. Housing density and bacterial loading in urban streams. Journal of Environmental Engineering. pp 1177-1180.